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EARTH RESOURCES APPLICATIONS OF THE SYNCHRONOUS EARTH OBSERVATORY SATELLITE (SEOS)

by

D. S. Lowe, J. J. Cook, et al.
Infrared and Optics Division

ENVIRONMENTAL
RESEARCH INSTITUTE
OF MICHIGAN
FORMERLY WILLOW RUN LABORATORIES,
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16. Abstract

This report presents the results of a four month study to define earth resource applications which are uniquely suited to data collection by a geosynchronous satellite. While such a satellite could also perform many of the functions of ERTS, or its low orbiting successors, those applications have been considered here only in those situations where requirements for timely observation limit the capability of ERTS or EOS. Thus, the applications presented in this report could be used to justify a SEOS.

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PREFACE

This report presents the results of a four-month study to define earth resource applications which are uniquely suited to data collection by a geosynchronous satellite. While such a satellite could also perform many of the functions of ERTS, or its low orbiting successors, those applications have been considered here only in those situations where requirements for timely observation limit the capability of ERTS or EOS. Thus, the applications presented in this report could be used to justify a SEOS.

Following the definition of appropriate applications, those characteristics of the observations required for a meaningful SEOS experiment were identified, i.e., the set of observations required to demonstrate that the application is or is not a worthy candidate for an operational type SEOS. These applications were then analyzed to develop sensor requirements. The top ten applications were used to develop a SEOS mission profile.

ERIM disciplinary teams, charged with the detailed investigation and documentation of potential mission objectives (applications) for a synchronous earth observatory satellite (SEOS), as well as the numerous user groups and earth-science experts contacted in the course of this study, are in complete agreement that geosynchronous observation capability represents a highly significant advance in earth resources management. The more than thirty applications presented here are but a representative sample of the numerous areas in which timely data can be of inestimable value in monitoring, developing and managing our earth resources.

The monitoring of natural disasters and catastrophic events of characteristically transient nature is clearly and uniquely suited to observation from a geosynchronous platform. However, as the pressures on our environment and limited resources intensify, the need for timely, intelligent, and informed management decisions is hardly less immediate. This, in turn, requires a reliable system for collecting accurate and timely information, unimpeded by the obscuration of cloud cover coupled with the periodic revisit times of low-altitude satellite platforms or schedule and transient delays associated with aircraft operations. Finally, there are numerous earth resource phenomena which exhibit transient behavior on a time scale comparable to the more visible disasterous events. The full utilization of such characteristics requires equally critically timed, and often repetitive, observation.

The applications discussed herein, and in particular, the detailed documentation included in Appendices A through F, is the combined effort of numerous personnel listed below. Their outstanding contribution and experience in the various application areas along with the guidance received from Dr. Louis Walter, GSFC Technical Monitor, has been essential in the preparation of this survey document.

D. S. Lowe, Principal Investigator
J. J. Cook, Program Manager

B. N. Haack
L. B. Istvan
D. R. Lyzenga
R. F. Nalepka
F. C. Polcyn
D. L. Rebel
N. E. Roller
B. C. Salmon
I. J. Sattinger
R. E. Turner
R. K. Vincent
C. T. Wezernak

R. A. Summers*
W. L. Smith*
B. MacDonald*

*System Planning Corporation

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EARTH RESOURCES APPLICATIONS OF THE SYNCHRONOUS EARTH OBSERVATORY SATELLITE (SEOS)

1.0 INTRODUCTION

For more than a decade, satellite-borne instruments, in programs such as TIROS, Nimbus, and ATS, have been providing information about the earth and its atmosphere. Much of this information, derived from a large-area synoptic view, from remote and inaccessible areas, or through the rapid assessment of dynamic events, would otherwise have been unavailable.

Although much of the initial orbital effort was devoted to meteorological applications, the simultaneous observation of earth surface features, augmented by an extensive aircraft and ground-based measurement program, provided impetus for the investigation of earth resource applications. Imagery obtained during the manned Gemini and Apollo series clearly demonstrated the feasibility of orbital collection of earth resource data, and the success of the first low-orbiter satellite specifically devoted to these applications (ERTS-1) surpassed expectations of even the more optimistic investigators. The current SKYLAB sequence (EREP) is expected to still further define and demonstrate the considerable benefit to be derived from the application of orbital data collection to earth resource problems.

To date these programs have concentrated on low-altitude platforms giving repetitive coverage of much of the earth's surface, but at varying intervals of time (e.g., ERTS-1, once every 18 days). Given the presence of an interfering cloud cover, such low altitude satellites can result in very long intervals between successive images of a specific area. For example, ERTS-1 was launched and began collecting data in July 1972, but an acceptably low cloud-cover image of the northeastern quarter of Michigan's lower peninsula was not obtained for nearly one year (June 1973).

While current and planned programs will result in a number of such low-altitude orbiting platforms, and one can postulate an appropriate observation sequence to partially alleviate this problem, there are many earth resource-related phenomena which exhibit such short-term temporal behavior as to require an unacceptably large number of low altitude platforms. In such cases, the only practical approach appears to be through the rapid response-interactive capability of a geosynchronous satellite.

NOAA (1971) has noted that natural disasters constitute one of four key problems involved in monitoring the global environment. Such disasters (summarized by NASA/GSFC, 1971, to include "hurricanes, tornadoes, forest fires, floods, frost and disease and insect crop damage") often involve temporal behavior requiring critically timed and/or near continuous observation. While it has been demonstrated that remote observation can materially aid in reducing the harmful effects of such disasters, it must also be noted that critical timing is the key to appropriate preventative or corrective action.

The User Applications Panel, in its contribution to the report of the Advanced Imagers and Scanners Working Group (NASA/GSFC, 1972 a.) concluded that "some applications require a high frequency of observation, perhaps daily or even hourly, thus requiring development of geostationary observation capability." Numerous other studies and reports have reached similar conclusions (Booz-Allen, 1967; USDI-EROS, 1969; Colvocoresses, 1970; Doyle, 1971). Colvocoresses (1970) terms the potential value of a geostationary platform "enormous ... offering a possible solution to the survey problem which is fundamental to resource management."

This report presents the results of a four-month study to examine NASA's earth resource program and determine if its effectiveness can be improved substantially through the use of a Synchronous Earth Observatory Satellite (SEOS). In this short time period, much of the effort was devoted to establishing what earth resource applications require critically timed observations.

Some thirty applications were considered to require a SEOS and the remaining effort was used to obtain a "first cut" of the sensor and system requirements.

This study is limited to investigation and documentation of potential earth resources mission objectives. A parallel study, conducted by the Space Sciences and Engineering Center of the University of Wisconsin*, evaluated the potential meteorological uses of an earth synchronous satellite. These two studies must be merged in order to establish the full potential of SEOS, to define SEOS requirements, and to scope the mission profile and data collection capacity.

In an initial study such as this (pre-phase A), one must fight the temptation to be thorough in all facets of the problem. Before SEOS is launched, many studies and detailed analyses will be conducted. This study does not attempt to design the sensor system, but establishes an authoritatively backed need for SEOS, defines its performance requirements, and confirms the feasibility of a SEOS mission.

Section 2 of this report reviews the current and proposed NASA Earth Observation Program. This provides the background against which the need for SEOS is evaluated. Section 3 provides a general description of SEOS and its capability. This information was used as a guideline as to what measurement capability one can expect from a sensor system in geostationary orbit. Section 4 presents a general treatment of the problem of cloud cover and its effect in restricting observational capabilities of low-orbiting, non-synchronous satellite platforms.

The heart of the report is embodied in Section 5, SEOS Applications. This section details the methodology for establishing the earth resource applications unique to SEOS and summarizes the results. Back-up narrative and tabular description of each application is found in Appendices A through F.

In Section 6, the data on applications is used to define a SEOS mission profile. Section 7 presents the conclusions and recommendations.

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*Soumi, V. E., et al, 1973, Meteorological Uses of the Synchronous Earth Observation Satellite, 30 July

2.0 EARTH OBSERVATION PROGRAM

In order to properly assess the importance and probable impact of an earth resources geostationary platform, it is necessary to consider the framework of current and planned systems for the time-frame through the early 1980's.

Table 1 shows both the current program and the planned program schedules for CY 72 through CY 82 as revised from the NASA Earth Observation Program Memorandum (NASA, 1972). The table includes meteorological, earth resources survey, and pollution control mission schedules. Further revision is anticipated in the planned program.

The present study was, by explicit direction of NASA/GSFC, limited to the investigation and documentation of potential earth resources mission objectives. A parallel study (also for NASA/GSFC), conducted by the Space Science and Engineering Center of The University of Wisconsin , evaluated the potential meteorological uses of an earth synchronous satellite. Therefore, in the following sections only the earth resource survey missions are discussed, except in those cases where meteorological missions are pertinent to earth resources. Section 2.1 discusses current Earth Observation Programs, while Section 2.2 describes the objectives and technical plans for Planned Earth Observation Programs, other than SEOS. Section 3.1 briefly reviews the objectives and technical requirements of SEOS as envisaged by NASA-Hq for the FY 73 planning process. Finally, Section 3.2 considers the relationship of SEOS to other earth observation programs.

2.1 Current Earth Observation Programs*

The current Earth Observation Program includes survey missions of ERTS-1, ERTS-B and Skylab (EREP) which are discussed below, as well as the following meteorological missions:

*Summarized from NASA (1972), NASA/GSFC (1971), Mathews (1973), NASA/GSFC (1973), NASA/MSFC (1973), NASA;OMSF (1972.

Table 1

EARTH OBSERVATIONS MISSION SCHEDULES

	CY72	CY73	CY74	CY75	CY76	CY77	CY78	CY79	CY80	CY81	CY82
CURRENT PROGRAM											
Nimbus E-F	0		0								
*ERTS A-B	0				0						
SMS A-B		0	0								
EREP (Skylab)		0									
TIROS N						0					
PLANNED PROGRAM											
ERTS C							X				
SMS C						X					
**Nimbus G (Pollution)						X					
Shuttle Sorties								X	XX	XX	XX
EOS A-D							X	X	X	X	
ERS Operational Prototype A-D								XX	XX		
SEOS A-B									X		X
SMS E-F										X	X
TIROS O										X	

*Current Congressional discussion suggests a 1974 launch date for ERTS-B.

**FY 74 New Start.

0 = Approved program

X = New starts FY74-78

(1) SMS A-B. Synchronous meteorological satellite, part of the geostationary operational environmental satellite series (GOES), to provide the operational capability to keep significant portions of the earth's cloud cover under surveillance, acquiring information on rapidly developing weather features.

(2) Nimbus E-F. Spacecraft for testing new meteorological techniques to expand atmospheric remote sensing to cloudy regions and to higher altitudes through utilization of new regions of the electromagnetic spectrum.

(3) Tiros N. A prototype of a third generation operational meteorological satellite to provide advanced data needed for the national operational system and for the Global Atmospheric Research Program (GARP). Emphasis will be on quantitative measurement of the vertical structure of the atmosphere by employment of a very high resolution four-channel scanning radiometer.

ERTS-1 and ERTS-B

The first ERTS was launched in 1972, representing a highly significant accomplishment in the Earth Observation Program. The objectives of ERTS-1 and subsequent ERTS launches are to put automated earth sensing spacecraft into medium altitude near polar orbits and to perfect the ground data handling systems for processing data for a variety of experiments in the disciplinary areas of agriculture, forestry, geology, hydrology, land use, environmental quality and oceanography. The satellite has demonstrated its ability to obtain a large volume of imagery over several seasons, showing changing surface characteristics which are applicable to earth resources surveys. Over the extended program, it is anticipated to obtain data relevant to earth resources management and to provide a basis for decisions as to the value of developing operational ERTS-type earth resource survey systems.

The ERTS sensors are capable of obtaining both visible and near infrared imagery of the earth's surface. The principal sensors are the return beam vidicon (RBV) multispectral television camera system, which is currently inoperative due to technical reasons, and the multispectral scanner (MSS), which has provided much excellent imagery, superior to that anticipated by the principal investigators.

ERTS/MSS has demonstrated the following capabilities:

(1) Repetitive synoptic coverage simultaneously in four spectral bands.

(2) Provision of 10,000 sq mile images in single spectral bands, in any combination, or as color composites.

(3) Provision of data required to locate specific terrain features or to produce a wide variety of thematic maps and overlays.

(4) Automated machine processing of digital data tapes.

(5) Scans covering a swath of earth 185 km wide during each orbital path (with repetitive coverage each 18 days) in the four spectral bands.

ERTS-1 has provided for systematically viewing earth resource characteristics over several seasons under similar lighting conditions. The data acquired is transmitted to receiving stations in Fairbanks, Alaska; Goldstone, California; and Greenbelt, Maryland, where it is recorded on tape. The tape is sent to the GSFC ground data handling facility where it is processed and reproduced for use by the various investigators. It is also processed for public sale through the USDI-EROS center at Sioux Falls, South Dakota.

ERTS-B scheduled for 1976, will be identical to ERTS-1 except for the addition of a thermal IR channel on the multispectral scanner. Options to launch ERTS-B at an earlier date, without the thermal capability, are being evaluated at this time. Thus, no firm conclusions can be drawn, as to its final operational sensors or capability, at this time.

<u>Earth Resources Experimental Package (EREP)</u>

The EREP was flown on Skylab in June 1973, the first manned space station. The Skylab is designed for an orbital life of 240 days during which time one crew has visited for a 28-day period and two subsequent crews will visit for two 56-day missions. The EREP is a man-tended facility designed to acquire data over a large range of the electromagnetic spectrum which is of value to earth survey disciplines.

The sensors include the following experiments:

S-190A Multispectral photographic facility
S-190B Earth terrain camera
S-191 Infrared spectrometer
S-192 Multispectral scanner
S-193 Microwave radiometer/scatterometer/altimeter
S-194 L-band microwave radiometer

These consist of an array of six, boresighted, precision cameras designed to operate within select bands in the 0.4 to 0.9 micrometer portion of the spectrum; a 45 cm (18-inch) focal length camera; a visible and infrared filter-wheel spectrometer which provides continuous data over the 0.4 to 2.4 micrometer and 6.2 to 15.5 micrometer bands; a multispectral scanner which divides the spectrum (0.4 to 12.5 micrometers) into thirteen bands; a 13.9 GHz microwave system which operates in either a passive (radiometer) or active (scatterometer) mode and shares its one-meter (40-inch) antenna with an altimeter experiment; and a 1.4 GHz phased array radiometer antenna. The infrared spectrometer is boresighted with a crew-operated viewfinder and tracking system. Using this system the crew will seek and track ground sites as small as 440 meters (1300 feet) in diameter. A 16 mm camera boresighted with the telescope photographs the scene as the spectrum is recorded.

All of the EREP sensors are operated by the Skylab crew, using a Command and Display Panel. Data acquired by the sensors are recorded on film and tape and are returned to earth by the crew in the command module.
The Skylab data will be correlated with information from ground truth sites, aircraft, and ERTS. The microwave experiments are of particular interest inasmuch as they represent the first opportunity to develop an all-weather system not severely attenuated by rain or cloud cover. Only large space platforms are adequate for the installation of microwave antennas. EREP

sensors provide coverage of similar optical regions as ERTS sensors, using different techniques; however, the EREP sensors provide improved spectral resolution. ERTS missions are placed in sun-synchronous orbits from which all of the earth will be viewed repetitively at the same local time. The 50° inclination of Skylab will, on the other hand, provide viewing of only about 70 percent of the earth's land area. Repetitive coverage of ground sites are provided for but at different local times. A major function of the crew involves coordination with ground-based activities and Mission Control to update the scheduling of EREP. Real time decisions are required relating to local weather and cloud cover conditions.

2.2 Planned Earth Observation Programs* (Except SEOS)

Meteorological Programs

The following are meteorological programs pertinent to SEOS:

(1) SMS-D. An atmospheric sounder for the Geostationary Operational Environmental Satellite program to be tested on R&D spacecraft SMS-D, with the objective to obtain quantitative information of time variations of the three-dimensional mass distribution of the atmosphere from a stabilized platform positioned at geostationary altitude.

(2) Nimbus G. A sun-synchronous near polar Nimbus similar to Nimbus E and F, with a mission to measure the structure and energetics of atmospheric interactions such as air-surface boundary conditions, large scale atmospheric motions, and atmospheric pollution.

(3) SMS E&F. Advanced prototype satellites and sensors for a second generation series of operational geostationary meteorological satellites capable of meeting the National Operational Meteorological Satellite System (NOMSS) requirements as specified by NOAA. The two spacecraft will be positioned, one over the Atlantic and one over the Pacific, off the U.S. coasts.

(4) Tiros O. An advanced operational prototype polar orbiting meteorological satellite for 4th generation environmental sensing for NOMSS.

*Summarized from NASA Hdq (1972); NASA/MSC (1971); Mathews (1973); Sharma, et al (1973); Orrok (1972); and NASA/GSFC (1972 b.)

ERTS-C

Initial plans for ERTS-C are to obtain oceanographic resource data for the purposes of identifying nutrient rich areas of the oceans and their temporal changes, obtain data on phenomena characterized by temperature such as thermal pollution, and to broaden economically significant earth resource applications.

The ERTS-C payload will include the MSS with the thermal IR channel, two panchromatic RBVs with double the resolution of ERTS-1 or B, plus an ocean scanning spectrometer for ocean color studies. ERTS-C will extend the studies of agricultural, hydrological and environmental sensing started under previous ERTS missions.

Shuttle Sorties

Earth applications studies are uniquely suited to shuttle sorties for purposes of instrument development and for the study of short term phenomena. Proposed sortie missions of seven days duration at 100 nm altitude are readily adaptable to Earth Resource Survey Applications requirements. For such missions experimental payloads may comprise both operational and developmental experiments. Operational experiments would include surveys of slowly varying phenomena such as delta or coastal studies, agricultural, and forestry patterns and those requiring intermittent observations rather than constant surveillance. Short term phenomena such as catastrophic events would require "contingency" missions which could be employed, but only under the most demanding circumstances.

The sortie mode will permit scientists from various earth resource disciplines to participate in target selection and sensor development on short duration missions. The capability of carrying a large payload will permit sensing over the entire pertinent electromagnetic spectrum, will allow intercomparison of several types of sensors by the investigator, and will tend to assure the reliability of instrument performance. This mode is considered to be particularly useful where seasonal or less frequent sensing is desired, data is not available from other systems, on-board data processing or mission specialists are required, and/or few observations from low altitude orbit will provide sufficient data.

Earth Observatory Satellites (EOS) A-D

The Earth Observatory Satellites (EOS) are seen as a series of orbital platforms for the conduct of research leading to the development of advanced remote sensing devices and techniques applicable to earth resource surveys. EOS will assume the research now conducted on ERTS and Nimbus. Project objectives stated by the NASA Office of Applications include provision of the capability for the acquisition of advanced, remotely-sensed data for studies of terrestrial surveys, meteorology, oceanography, and environmental monitoring/ecology, and support of research on the applicability of advanced instrumentation concepts and data management approaches for future operational use.

The EOS system is considered essential to the development of an all-weather remote sensing system. Sensors to be developed on EOS missions include a seven-channel thematic mapper, two framing cameras, a sea surface temperature imaging radiometer, an ocean color scanning photometer, a five-channel passive microwave radiometer, an upper atmosphere sounder, and a gaseous pollution detector.

The EOS satellite will follow the design of ERTS and Nimbus; however, it will have an improved capability for positioning and altitude, a broader viewing area for the sensors, and a high (30 Mbs) data rate storage and transmission system.

Earth Resources Survey Operational Prototypes, A-D

The ERSOP program has the objectives of developing an operational system which will be of particular use for monitoring land use changes, geologic mapping, vegetation inventories and surface water management. This operational system will be designed to meet user agency needs that develop from the findings of the ERTS programs. Inasmuch as initial requirements derived from ERTS experience will most likely be widely diversified, the early ERSOP missions are envisioned as a group of four satellites in low polar orbit to investigate specific areas with high resolution and high repetitive data in conjunction with aircraft. The spacecraft may fly duplicate payloads at different orbits to optimize illumination conditions.

3.0 GENERAL SYSTEM CONCEPT OF SEOS

3.1 System Configuration*

The SEOS program calls for the development of a system for continuous viewing from a geostationary satellite and permitting time-dependent multispectral analysis. Such a system would provide opportunities for viewing of short-lived events while they occur or at the first cloud free opportunity, or for monitoring time-variable environmental phenomena. Among the more important short-lived events are transient hazardous occurrences such as fires, floods, volcanic eruptions, earthquakes and storms, against which precautionary action might be taken, or where emergency aid or public health actions might be required. In addition, SEOS observations will assist in the conservation or exploitation of natural resources by monitoring such environmental phenomena as changes in snow pack as related to water supply, run-off and flooding, changes in ocean surface temperature patterns as related to marine food resources, and changes in solar radiation reflectivity studies of agricultural crops as are pertinent to irrigation schedules or plant diseases.

The currently visualized SEOS system will include a large reflective telescope with a scanner system adequate to achieve "ERTS-type" ground resolution in the reflective solar bands and reduced resolution in the thermal infrared. A data collection system will be included to provide data from in-situ sensors. SEOS-A is proposed for launch in 1980, with SEOS-B to be launched in 1982.

It is conceived that SEOS will be uniquely adaptable to broad-area phenomena which are transient, or those phenomena which require constant monitoring to detect significant (and perhaps rapid) changes in character. Generally, these phenomena are expected to be of such areal extent as to require an EIFOV of 100 to 1000 km, and in some cases to require an observation of several hours dwell time, with possibilities of repeated viewing of a large area within minutes or hours. As currently envisioned, SEOS will have the required position

*Summarized from NASA/MSC (1971); NASA/GSFC (1971).

and sensor range, and will be able to use its sensing techniques in conjunction with data provided simultaneously from some 150 automated sensor platforms. The possibility of selecting a wide range of view times will increase the likelihood of clear weather observations.

One possible launch condition would provide for the SEOS spacecraft standing at 100° W longitude in a 35,870 km geosynchronous orbit. In such an orbit, full imagery coverage (elevation angle 35°) would include all of the coterminous USA, all of Latin America, and all except the eastern and southern tips of South America. Given an appropriate motivating event, coverage could be extended east or west (e.g., to view much of Europe and Africa) as long as the antennas are in view of GSFC. The scanner could operate as a high resolution, portable, framing camera or a wide area scanner. Two suggested modes of operation (GSFC, 1971) are shown in Table 2.

Table 2. Suggested Mode Operation of SEOS Scanner

	Mode I	Mode II (4 bands)			
FOV, km	200 x 1000	740 x 750			
Observation time, min.	10	30	1.7	1.7	1.7
Ground resolution, km	0.2	1.5	0.5	1.5	5.0
Spectral bands, micrometer	0.8-1.2 0.2-0.7	3.4-4.1 0.4-0.8	0.8-1.2	10.5-12.5	6.3-6.7

Relationship of SEOS to Other Programs

The current successful ERTS-1 and Skylab missions have provided valuable sensor data on earth resources survey phenomena. Nimbus, Tiros and other meteorological satellites programs have provided essential data on cloud cover and the nature of the atmosphere. Although there have been major advances, there is a standing need for improved spectral, spatial and temporal resolution, and for the capability for off-nadir pointing of sensors from automated satellite platforms. In particular, phenomena with rapidly varying parameters as well as subtle, large-scale changes require special capabilities if these events are to be adequately monitored.

The SMS operational system was designed for sensing weather features from a geosynchronous position. Many earth resources phenomena also require continuous monitoring or measurement at critical times, hence dictate observation from a geosynchronous satellite. Of specific importance is the capability for continuous observation of short time-constant phenomena on the earth's surface and the use of a geostationary data relay, particularly for rapidly varying phenomena. Plans for meeting these requirements include both EOS and SEOS R&D missions.

EOS is foreseen as a major step in the improvement of sensing instrumentation at lower altitude. SEOS will provide an early capability for continuous viewing of the earth with spatial and spectral capabilities compatible with the needs of earth resource applications. This will facilitate attack on regional environmental problems which relate to such transient phenomena as fire, floods and geologic disasters. The continuous monitoring of subtle, large-scale changes in earth and ocean phenomena will also be feasible. In addition to its individual capability for continuous viewing of the earth's terrain and ocean surfaces, the SEOS observation should provide the basis for synergistic combination with lower altitude spacecraft and aircraft observations. Such a system will provide data relevant to saving lives, reducing property damage, marketing produce, and strengthening the basis of our economy and standard of living through optimum utilization and conservation of our resources and preserving the quality of our environment.

3.2 Orbital Requirements

In addition to the nominal SEOS stationary 24 hour orbit whereby the satellite nominally sits over a specific point of longitude on the earths equator, there are a number of other options that may be considered which involve variations in: (1) inclination of the orbital plane, (2) eccentricity of the orbit, and (3) the argument of perigee for the eccentric orbit (i.e., "ascending node" the location of the perigee point with respect to the equator crossing). The use of inclined orbits appears to have some potential attraction so that one may reach higher latitudes for nadir or near-nadir viewing. The employment of eccentric orbits seems to offer some potential attractiveness in terms of providing lower altitude, and hence higher spatial resolution, coverage for a certain area and for certain times of the day.

Some preliminary calculations have been made with the aid of the GSFC orbital computer program. Figures 1 and 2 show satellite ground (earth) traces, one for a low eccentricity orbit (0.05) and the other for a higher eccentricity (0.50) orbit both at an inclination of 45°. Also indicated are the latitudes of New York City, as a typical case for supertanker ports or spillage, and Valdez, Alaska as a typical case for pipeline monitoring. It should be noted that the "figure 8" effect produced by inclining the orbit tends to be wiped out for larger eccentricity (in excess of about 0.1).* It should also be noted that the inclinations should be reversed if perigee is desired over New York City or Valdez; this can be done simply by inverting the two figures. Accompanying these figures are Tables 3 and 4 indicating the altitude at each of the 24 hour points. Assuming a ground resolution of 100 meters from a stationary circular orbit (35,870 km) the changes in ground resolution resulting from the eccentric orbit are shown in these tables. It should be noted that, even in the high eccentricity case of Figure 2, the maximum gain from apogee to perigee in resolution is only about a factor of 4, which would correspond approximately only to a factor of two over a circular orbit. For the particular case shown, the effective resolution varies from 41 meters at perigee to 159 meters at apogee.

*Argument of perigee = -90°

Case Input
Semi-Major Axis = .13833393E 09
Time of Perigee Passage = .00000000
Eccentricity = .50000000E-01
Argument of Perigee = -90.000000
Right Ascension of Ascending Node = .00000000
Inclination = 45.000000
Longitude at to = .00000000
To = .00000000
Alpha 1 = .00000000
Alpha 2 = .00000000

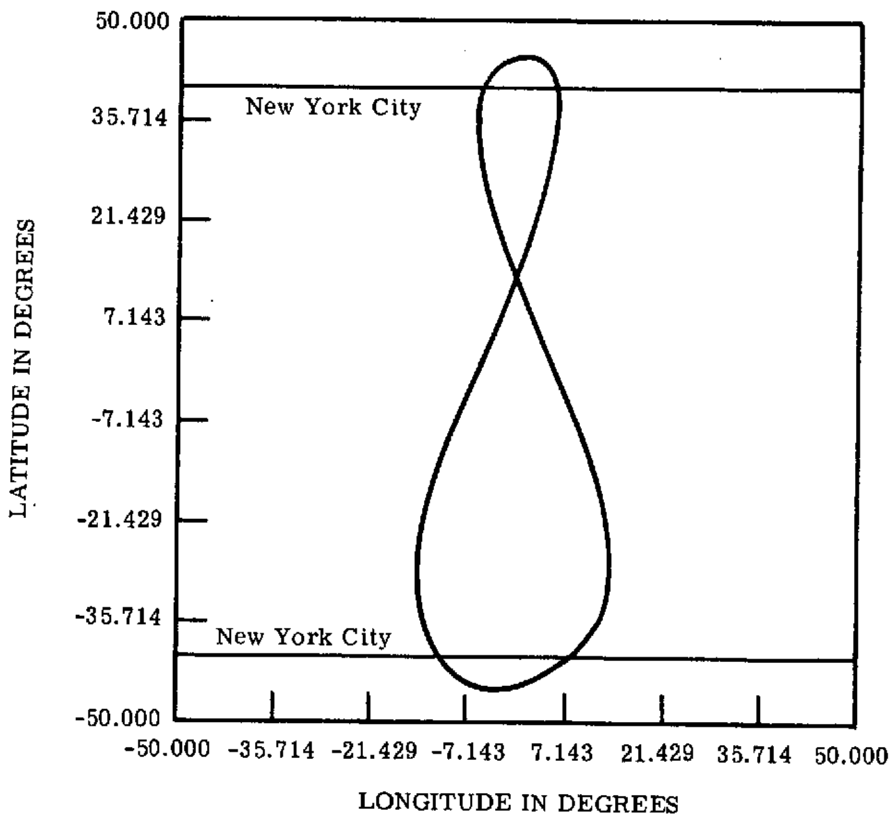

FIGURE 1. SATELLITE GROUND TRACE FOR LOW ECCENTRICITY ORBIT (0.05) AND 45° INCLINATION

Case Input
Semi-Major Axis = .13833393E 09
Time of Perigee Passage = .00000000
Eccentricity = .50000000
Argument of Perigee = -90.000000
Right Ascension of Ascending Node = .00000000
Inclination = 45.000000
Longitude at to = .00000000
To = .00000000
Alpha 1 = .00000000
Alpha 2 = .00000000

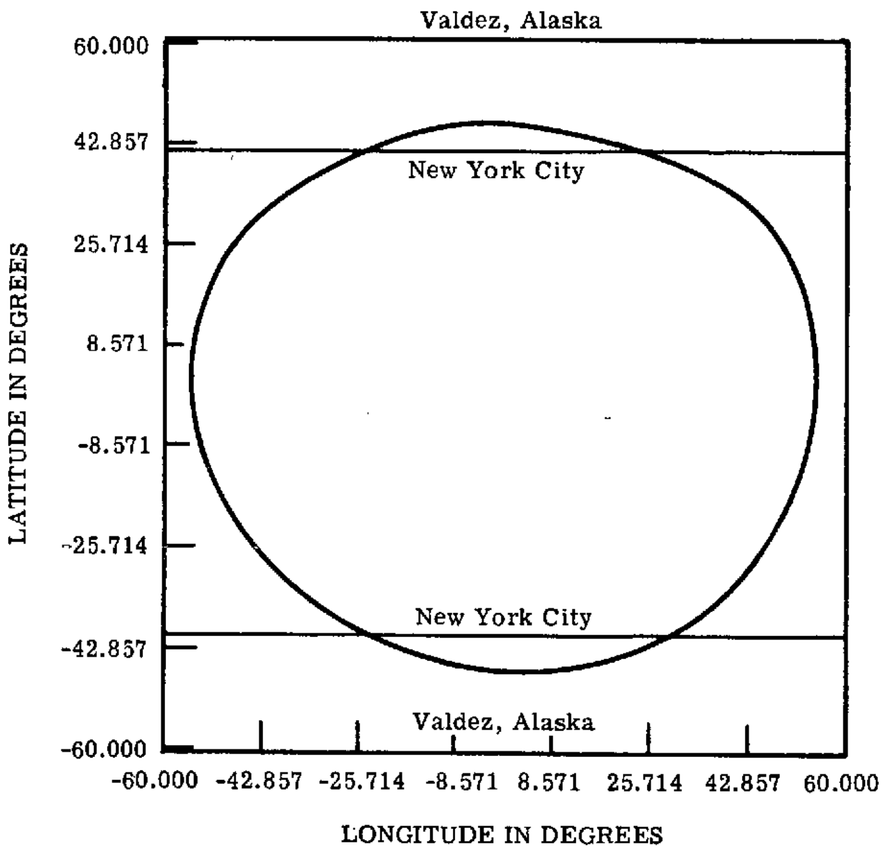

FIGURE 2. SATELLITE GROUND TRACE FOR HIGH ECCENTRICITY ORBIT (0.50) AND 45° INCLINATION

TABLE 3
Altitudes and Ground Resolution for
Eccentricity = 0.5
Inclination = 45°

POSITION	TIME (m)	DISTANCE (km) (Altitude)	RELATIVE GROUND RESOLUTION (m)
A	0	14,700	41
B	1	17,300	48
C	2	23,100	64
D	3	29,400	82
E	4	35,300	99
F	5	40,600	113
G	6	45,000	125
H	7	48,700	136
I	8	51,700	144
J	9	54,000	150
K	10	55,700	155
L	11	56,600	158
M	12	56,900	159
N	13	56,600	158
O	14	55,700	155
P	15	54,000	150
Q	16	51,700	144
R	17	48,700	136
S	18	45,000	125
T	19	40,600	113
U	20	35,300	99
V	21	29,400	88
W	22	23,100	64
X	23	17,300	48

TABLE 4
Altitudes and Ground Resolution for
Eccentricity = 0.05
Inclination = 45°

POSITION	TIME (m)	DISTANCE (km) (Altitude)	RELATIVE GROUND RESOLUTION (m)
A	0	33,700	94
B	1	33,800	94
C	2	34,000	95
D	3	34,400	96
E	4	34,900	97
F	5	35,400	99
G	6	35,900	100
H	7	36,500	102
I	8	37,000	103
J	9	37,400	104
K	10	37,700	105
L	11	37,900	106
M	12	37,900	106
N	13	37,900	106
O	14	37,700	105
P	15	37,400	104
Q	16	37,000	103
R	17	36,500	102
S	18	35,900	100
T	19	35,400	99
U	20	34,900	97
V	21	34,400	96
W	22	34,000	95
X	23	33,800	94

There is a considerable price to be paid for both inclination and eccentricity. In the case of inclination, one is faced with the regression of the nodes effect due to the earth equatorial bulge. This may be in the order of 5° a year. The price of eccentricity is a precession of the perigee at a rate which may be of the order of 15°/year. It appears that a 45° orbital inclination would require a correctional velocity increment of approximately 100 ft per second per year, which in accordance with a previous study (Booz-Allen, 1967) translates into about a 1% increment in satellite weight (incremental fuel only). The effects of eccentricity are somewhat larger and actually would in general require prohibitive velocity increments of several thousands of feet per second per year. However, an orbital inclination of 63.4° provides zero progression of perigee and may be a desirable configuration, if eccentricity seems to be worth it.

The preliminary assessment of the trade-offs indicates that the increases in resolution over part of the day to be achieved by eccentric orbits is probably not worth either being restricted to the 63° orbit or being required to supply very large amounts of velocity correction. The advantage in spatial resolution for a given sensor seems to be only about a factor of two for an orbit with as high an eccentricity as 0.5. There may be some advantages in inclining the orbit at zero eccentricity since a velocity increment of 100 ft per second per year translated into a 1% increase in satellite weight, may be viable. However, the disadvantage would come in the case of potential applications of a 6-satellite system, as described by Colvocoresses (Colvocoresses, 1970) which would have cartographic/topographic capabilities. These would depend on the increased precision in orbital determination and sensor attitude determination provided by a geostationary orbit. Some of this advantage would certainly be lost in the case of either inclination, eccentricity or both. The possibility of cartography with the 6-satellite system requires considerably more work to assess its feasibility. Another effect noted is the angular velocity of the sensor line of sight with respect to the satellite platform. It is noted that, if the satellite platform is earth-center-oriented, then the angular velocity of the sensor line of sight with respect to the platform is appreciably reduced. For the example shown in the study (Booz-Allen, 1967) (a 23-1/2° elliptic orbit), the relative slew rate would be 4-1/2° per hour for an initially oriented platform and only about 40 minutes of arc per hour for an earth-centered platform.

4.0 CLOUD COVER CONSTRAINTS

Remote sensing by satellite has made great strides in technical capabilities since the early days of the satellite era. Yet despite these strides, the problem of cloud cover has continued to impede the utilization of satellite data in the burgeoning number of earth resources applications.

By reducing or eliminating visibility on a stochastic basis, cloud cover makes the performance of any non-earth stationary viewing system uncertain. Where reliable availability of data is of paramount imprtance, cloud cover can be fatal to an application. Since a geosynchronous satellite, on the other hand, is virtually always above the area of interest, it will be able to scan the area during the potential breaks in the cloud cover.

Given an ERTS-type satellite with a frequency of passage of 18 days, the existence of an acceptable cloud cover level over a given location N percent of the time gives that location an effective coverage frequency of once every N/100 x 18 days. For regions characterized by high cloud cover, ERTS coverage thus becomes highly erratic, and such regions on occasion can go for many months without acceptable imagery. The Northeastern quarter of the Lower Peninsula of Michigan, for example, went from July of 1972 to June of 1973 before one good image was obtained.

The experience with ERTS coverage for 19 different U.S. locations is shown in Table 5 . Three different cloud cover levels are presented (i.e., <20%, <50% and <80%). While the maximum permissible cloud cover will vary from one mission objective to another, let us assume that for oil spill monitoring the cloud coverage must be less than 20%. For Santa Barbara, this presents little problem, since cloud coverage was acceptable 76% of the time. For the Schuylkill River northwest of Philadelphia, however, cloud coverage was acceptable only 25% of the time, giving ERTS an effective mean frequency of coverage of only once every 72 days. Such effective coverage would most often be of little use in the event of an oil spill, such as occurred on the Schuylkill on June 27, 1972 and lasted until the middle of July. Even if 40% cloud cover is permitted, the Schuylkill location still gives ERTS effective coverage of only once every 31 days based on this data.

This effect is seen even more dramatically for the Mississippi Delta region. One of the seven sites examined by the government as a possible supertanker port, this area had only one ERTS passage out of 15 in which cloud cover was less than 20%. If this were to be generally true, ERTS would provide effective coverage of this location only once every 280 days. Even if this experience is untypical for the area, the ever-present possibility of encountering such a "3σ case" of 15 cloudy days in a row must be considered.

Making a few assumptions, the information in Table 5 can be used to assess the likelihood of a succession of N cloudy days. If it is assumed that the cloudiness encountered by ERTS is typical for each location, and that this is an equal a priori probability p, the probability of encountering N unacceptably cloudy days in succession is simply p^N. The results for the locations in Table 5 are given for a cloudiness level of $\leq$20% in Table 6 and <50% in Table 7. Actually, these figures are not quite accurate since a cloudy day is not uncorrelated with previous cloudy days and there are seasonal variations, errors in data, and other factors that will affect the results. However, the trends are probably valid, and this approach does illustrate the general cloud cover problem.

For applications that demand very little cloud cover, Table 5 portrays the likelihood of a location going for many orbits without receiving adequate coverage. Were a supertanker port to be built in the Mississippi Delta region and were oil spill surveillance to require less than 20% cloud cover, Table 6 indicates that there would be almost one chance in four of that port going for 21 satellite passes (over one year for ERTS) without useful coverage. Even if oil spill surveillance could be performed with up to 50% cloud coverage, there would be almost one chance in ten of the proposed port of Valdez, Alaska, going without coverage for ten satellite passes (six months for ERTS). Tables 6 and 7 show that for a number of locations of interest, a non-synchronous EOS runs the risk of failing to provide coverage for appreciable lengths of time. The precise nature of this risk requires further definition of cloud cover restrictions on applications, further refinement of cloud cover data, assessment of the role coverage overlap plays, and cloudy day correlation studies.

TABLE 5. ERTS CLOUD COVER EXPERIENCE FOR SELECTED U. S. SITES

Site	No. of ERTS Passes	No. of Passes With Specified Cloud Cover			Comments
		≤20%	≤50%	≤80%	
N. Schuylkill River	32	8	13	15	Oil spill, 6/27-7/15/72
Santa Barbara	17	13	13	16	Off-shore oil drilling, site of famous spill
Los Angeles	17	8	14	15	Brush fire
Cape Hatteras	28	3	8	18	Oil spill, 9/14-9/19/72, no ERTS coverage
Portland, Maine	23	3	9	12	Oil spill, 7/22-10/4/72, six ERTS passes; only one clear day six weeks after spill
Salem, Massachusetts	23	4	13	16	Waste oil leak, 9/27-9/30/72, no ERTS coverage although acceptable cloud cover during part of 9/28/72
Bonneville Dam	29	7	11	21	Snow melt
Northeastern Oregon	20	6	11	15	Snow melt
Southwest Iowa	25	12	17	21	Floods
Machiasport, Maine	25	4	8	11	Possible supertanker port
Raritan Bay, N. J.	36	9	19	23	Possible supertanker port
Sandy Hook, N. J.	27	8	15	19	Possible supertanker port
Cape May, N. J.	31	9	14	16	Possible supertanker port
Delaware Bay	37	9	15	18	Possible supertanker port
Mississippi Delta	15	1	5	10	Possible supertanker port
Galveston-Freeport, Texas	31	4	14	23	Possible supertanker port
Valdez, Alaska	28	3	6	19	Alaskan Pipeline Shipment Port

TABLE 6. PROBABILITY OF N PASSES
WITH 20% OR MORE CLOUD COVER IN SUCCESSION

LOCATION	CLOUDY PASSES IN SUCCESSION					
	1	3	6	10	21	50
N. Schuylkill River	.750	.422	.178	.056	.0024	--
Santa Barbara	.235	.013	.00017	--	--	--
Los Angeles	.529	.148	.022	.0017	--	--
Cape Hatteras	.893	.712	.507	.322	.093	.0035
Portland, Maine	.870	.658	.432	.247	.053	.0009
Salem, Mass.	.826	.564	.318	.148	.018	.0001
Bonneville Dam	.759	.437	.191	.063	.003	--
N.E. Oregon	.700	.343	.118	.028	.00039	--
S.W. Iowa	.520	.141	.020	.0014	--	--
Machiasport, Maine	.840	.593	.351	.175	.026	.0002
Raritan Bay, N.J.	.750	.422	.178	.056	.0024	--
Sandy Hook, N.J.	.704	.348	.121	.030	.00062	--
Cape May, N.J.	.710	.357	.128	.032	.0007	--
Delaware Bay	.757	.433	.188	.062	.0029	--
Mississippi Delta	.933	.813	.661	.502	.235	.0318
Galveston Freeport, Texas	.871	.661	.437	.251	.055	.001
Valdez, Alaska	.893	.712	.507	.322	.093	.0035

TABLE 7. PROBABILITY OF N PASSES
WITH 50% OR MORE CLOUD COVER IN SUCCESSION

LOCATION	CLOUDY PASSES IN SUCCESSION					
	1	2	3	5	10	15
N. Schuylkill River	.594	.353	.209	.074	.0054	.0004
Santa Barbara	.235	.055	.013	.0007	--	--
Los Angeles	.176	.031	.0055	.0002	--	--
Cape Hatteras	.714	.510	.364	.186	.035	.0064
Portland, Maine	.609	.371	.226	.084	.0070	.0006
Salem, Mass.	.435	.189	.082	.016	.0002	--
Bonneville Dam	.621	.385	.239	.092	.0085	.0008
N.E. Oregon	.450	.203	.091	.018	.0003	--
S.W. Iowa	.320	.102	.033	.0034	--	--
Machiasport, Maine	.680	.462	.314	.145	.021	.0031
Raritan Bay, N. J.	.472	.223	.105	.023	.0006	--
Sandy Hook, N. J.	.444	.198	.088	.017	.0003	--
Cape May, N. J.	.548	.301	.165	.050	.0025	.0001
Delaware Bay	.595	.354	.210	.074	.0055	.0004
Mississippi Delta	.667	.444	.296	.132	.017	.0023
Galveston Freeport, Texas	.548	.301	.165	.050	.0025	.0001
Valdez, Alaska	.786	.617	.485	.299	.090	.027

5.0 SEOS APPLICATIONS

In the effort described in this report, ERIM was directed to assess the capability of a synchronous earth observatory satellite (SEOS) to provide data of importance to resource management and, specifically, to establish mission requirements and implementation concepts for such a system. Among the requirements of this effort is the identification of those application areas and observational characteristics uniquely suited to data collection from an earth synchronous platform. Such applications areas were initially suggested to include the observation of environmental threats and disasters, such as floods, pollution, destructive shore processes, tidal actions, currents, forest fires, and crop freezes and stresses. In addition, it was envisioned that geostationay observation could provide the capability to more efficiently survey water supply, soils, crops, forests, land use, shore processes and marine resources. Finally, the feasibility of conducting such surveys, or of monitoring threats and disasters using geosynchronous satellite sensors, must consider data processing and dissemination, as well as the probabilities of successful observation of pertinent phenomena given cloud cover, an event's transient nature and system orbital parameters.

In regard to events of a transient nature, the Smithsonian Institution maintains a Center for Short Lived Phenomena (CSLP) which (since 1968) has operated a global environmental alert system for the rapid communication of information on short-lived phenomena of the natural environment. In defining earth resources applications for detailed investigation in the present study, the lists and tabulation of hazardous or urgent events compiled by that Center were surveyed and considered. More detail on the categories and CSLP classification are included in Appendix G.

5.1 Method of Defining Applications

As an initial step in identifying appropriate application areas, ERIM organized a number of disciplinary teams, thoroughly familiar with the user needs and data requirements associated with specific earth-science studies. These teams were charged with the analysis and documentation of pertinent characteristics of potentially useful observables associated with each mission objective (application); and with the analysis of the problem of remotely sensing these observables from a geostationary platform. They were further requested to describe those radiometric measurements (required to meet identified application area needs) which would help define instrumentation and data processing requirements as well as provide an analytic demonstration of the feasibility for attaining user (application) goals. Finally, they were asked to assess the SEOS advantage of assured acquisition of mission objectives in the absence of unacceptable cloud cover versus the probability of an unobscured ground trace for non-geosynchronous orbital platforms.

Diciplinary teams (including personnel intimately involved in remote sensing applications in various earth science disciplines) performed literature searches and personal or telephone interviews and visits with numerous users and recognized experts in their respective earth-science fields, in arriving at the 32 potentially useful application areas listed in Table 8. The initial list of applications was considerably shorter than Table 8 primarily because many of the applications were presented in a more general light. For example, pollution detection was presented as a single application rather than the final listing as three applications (solid, oil, and thermal). In defining each application, we attempted to be specific as possible so as to better define the sensor requirements of resolution, spectral bandpass, and area of coverage. For example, the sensor requirements for wild fire detection is significantly different from wild fire monitoring so these were treated as separate applications. As a result of this process, the applications as listed are not entirely independent of one another. For example, "Monitoring Extent, Distribution, and Change of Snow Cover" is an application which provides inputs to two other applications, "Management of Irrigation" and "Flood Prediction, Survey, and Damage Assessment." The effect of arriving at overlapping applications was considered to be a small price to pay since generalized applications yield generalized sensor requirements.

TABLE 8. SEOS APPLICATIONS

A. Agriculture/Forestry/Range Resources (Appendix No.)

Detection & Assessment of Disease & Insect Damage to Cultivated Crops (A1)
Determination of Optimum Crop Planting Dates (A2)
Phenological Classification of Agricultural Crop Types (A3)
Detection & Assessment of Disease & Insect Damage to Forest Species (A4)
Forest Inventory & Valuation for Multiple-Use Management (A5)
Evaluation of Range Forage Resources & Grazing Pressure Assessment (A6)

B. Land Use Survey and Mapping

Management of Irrigation (B1)
Wildfire Detection (B2)
Wildfire Monitoring (B3)
Thematic Mapping (B4)

C. Mineral Resources, Geological, Structural and Landform Survey

Exploration for Geothermal Sources (C1)
Monitoring and Prevention of Aeolian Soil Erosion (C2)
Monitoring Water Erosion & Deposition (C3)
Monitoring Volcanic Regions (C4)
Prediction of Landslides & Avalanches & Monitoring Subsidence (C5)
Geomorphological Survey (C6)
Lithologic Survey (C7)
Earthquake Prediction (C8)

D. Water Resources

Flood Survey & Damage Assessment (D1)
Monitoring Extent, Distribution & Change of Snow Cover (D2)
Monitoring Lake & Sea Ice for Navigation (D3)
Monitoring and Analysis of Lake Dynamics (D4)

E. Marine Resources and Ocean Survey

Estuarine Dynamics as Related to Pollution Dispersal (E1)
Detection & Mapping of Shoal Areas (E2)
Detecting & Monitoring of the Development & Movement of Colored Water Masses (Plankton) (E3)
Ocean Dynamics (E4)
Detecting & Monitoring Fish Location & Movement (E5)
Detecting & Monitoring Iceberg Hazards (E6)

F. Environment

Detecting & Monitoring Thermal Water Pollutants (F1)
Detecting & Monitoring of Water-Suspended Solid Pollutants (F2)
Detecting & Monitoring Oil Pollution (F3)
Analysis of Undesirable Heat Islands in Urban Areas (F4)

The analysis and documentation of important characteristics of each application was performed within basic guidelines and boundary conditions established as realistic for an eventual geosynchronous platform and discussed more fully in Section 3.1. These included an "ERTS-type" ground resolution and the capability to simultaneously monitor multiple spectral bands in the visible and reflective infrared. Finally, all studies were designed to identify applications wherein major goals could be attained (1) without thermal data, (2) with relatively coarse ground-resolution thermal infrared (an EIFOV of 1 km) and (3) those which were unattainable in the absence of thermal information.

Table 9 illustrates the format used to document pertinent information relative to each application. The right hand column describes the data to be entered. Entrees are shown in the form for one of the applications to better illustrate its use. In the text which follows, the rationale and ground rules for each data entry in Table 9 are discussed.

APPLICATIONS

In defining appropriate mission objectives, disciplinary teams were asked to survey the needs and goals of specific earth-sciences, and to identify those application areas uniquely suited to data collection from an earth synchronous platform. As such, these applications cast SEOS in the role of supplementing low-orbiting satellite programs and aircraft data collection missions rather than replacing or negating those techniques. Nevertheless, it is held that numerous mission objectives involve transient events or take place in the presence of an obscuring cloud cover, wherein the unique capabilities of SEOS are particularly important.

This column in Table 9 defines the ultimate application or goal for which geosynchronous data will be used, considering the specific user or user chain and the mission or need to be met by results of this data collection.

TABLE 9. SAMPLE TABLE OF DOCUMENTATION FOR INDIVIDUAL MISSION OBJECTIVES (APPLICATIONS)

EARTHQUAKE PREDICTION	APPLICATION	
USGS State and local government agencies Disaster relief agencies, local industry Oil and gas companies, Highway departments United Nations U.S. and Foreign governments	USER	
Temperature, especially diurnal variation Thermal inertia Dielectric Constant by DCS Visible and Reflective infrared reflectance	OBSERVABLE AND CHARACTERISTICS	
All	Season	TIME LINE OF EVENT
2 mos., Observation window: <1 hour	Duration	TIME LINE OF EVENT
1	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
6	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
Observations at two hour intervals for 30 days (360)	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Western U.S. and Western Central and South America	Geographic Location	SEOS OBSERVATION REQUIREMENTS
80 km x 320 km	Dimensions (m., Km.)	
500 m nominally, see attached graph (Thermal), 100 m for visible reflective IR.	EIFOV (m.)	SENSOR REQUIREMENTS
Broad-band visible and NIR; 10.5-12.5 μm Thermal band is required.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
$\Delta\rho$ = 1% ΔT = 1°C	$\Delta\rho$, ΔT (%, °C)	SENSOR REQUIREMENTS
Computer compatible tape and imagery	Format	DATA REQUIREMENTS
1 day routinely. <1 hour for significant changes	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Seismic readings, coordinates; DCS readout on temperature and conductivity.	Ancillary Data	DATA REQUIREMENTS
Field and A/C verification of thermal inertia effect; Analytical thermal model for seasonal and diurnal effect (A, F, A/C)	Study	INTERIM ACTIVITIES
24 mm	Level	INTERIM ACTIVITIES
1975-1980	Time Frame	INTERIM ACTIVITIES
Field/A/C	Platform	INTERIM ACTIVITIES
High	IMPORTANCE/ JUSTIFICATION	
Unique	SEOS UNIQUENESS	

USER

In each earth-science mission, the user may be a well defined agency or individual, or a chain of users, each depending upon remotely sensed data or the implementation of various plans or programs based upon the interpretation of such data. The teams were directed to identify who wants or needs this data, and to consider all action stages involved in implementing programs to meet application goals.

For example, a national level agency (e.g., USGS) could be envisioned as coordinator in collecting and disseminating information related to earthquake prediction, while state and local agencies would be responsible for specific action items, such as evacuation and/or relief activities. These agencies would in turn disseminate information to local industries, and emergency, law enforcement, and highway departments. The identification of such a user chain is essential in defining data needs such as timeliness or format.

OBSERVABLES AND CHARACTERISTICS

A given mission objective is associated with an event or sequence of events which, in some manner, modify the radiation field reaching the satellite platform. These events and their resultant radiative effect constitute the observable whose characteristics provide information of importance in the application area. A description of these anticipated characteristics is essential in defining sensor performance and system requirements. Teams were directed to provide a thorough description of the associated phenomena and spatial, spectral and temporal radiation observables to be expected.

TIME LINE OF THE EVENT

For the purposes of this study an event was defined to be the underlying mechanism giving rise to the radiative observable discussed above. As such, the precise event may vary from application to application, in either its spatial distribution or temporal behavior, giving rise to unique spectral characteristics. For earthquake prediction, a significant event might be defined as any marked change in thermal inertia, caused by a shift in ground water distribution, in an area of suspected activity. In an assessment of volcanic activity, it may be a change in thermal emission characterized by a specific spatial orientation relative to known sources, whereas in phenological classification of vegetation, it may be considered to be a predefined sequence of spectral changes exhibiting a particular temporal variation.

While each of these can be considered a single event of importance to a specific application, their time lines may be quite different, placing highly diverse requirements on system configuration, mission schedules and data collection procedures. Teams were asked to consider the time of year (if seasonally dependent) that a given event is most likely to be observed, or is most informative for a given application goal, as well as the duration and a probable sequence of events. These, in turn, define an observation window for transient events, or for critically-timed short-term conditions involved with longer-term phenomena.

OBSERVATIONAL REQUIREMENTS

In determining observation requirements for an application demonstration and a valid assessment of geosynchronous capability, it is quite likely that some replication will be necessary. Thus, there exists an estimated minimum number of events (as defined above) which is considered necessary for meaningful conclusions. Further, in certain applications, the observable or its specific characteristics may vary with geographic location or various environmental parameters (e.g., phenological change in a specific vegetation type). Thus, it is often desirable to observe more than one target or geographic region during a given event. Finally, a continuum of short-term changes or critical sequence of individual conditions could dictate several observations of each target area during a given event. Teams were required to assess these aspects of each application demonstration in order to define geographic coverage requirements and time constraints placed upon the total system. Approximate dimensions and anticipated shape of the proposed target areas is important since data collection techniques, time requirements and numerous other system demands may be highly different for a long narrow target (e.g., a linear fault zone) than for a square target of the same total area.

SENSOR REQUIREMENTS

The definition of sensor requirements (e.g., EIFOV) is invariably somewhat arbitrary, and often difficult to interpret, especially in terms of requirements established by the needs of widely diverse disciplines or applications goals. The User Applications Panel of the Advanced Imaging Sensors Working Group* states:

> The most troublesome term for the user group (and indeed for the workshop as a whole) was "Effective Instantaneous Field of View" (EIFOV). The sensor technology panels defined it very quantitatively as "the 50 percent response point on the MTF curve." While the user panel would have liked to affirm the same definition, it could not in fact do so. Such a definition was not sufficiently meaningful of itself to suit user needs.
>
> The definition of EIFOV used by this panel was "the minimum linear dimension on the surface (at nadir) at which user specified characteristics can be discerned." The most significant characteristic within the EIFOV was ... Sensitivity - smallest change in temperature or reflectivity which a user wishes to detect.
>
> (AISWG Report, p. 10)

Teams of the present study were directed to define an appropriate EIFOV for each wavelength band and each application area, according to the User Panel definition, and to establish sensitivity requirements consistent with that definition.

The resolution requirements for a given application is usually given as a single number, e.g., EIFOV = 100 meters. This number is not a hard and fast one and is generally representative of the maximum instantaneous field of view which a sensor can have and still collect useful data for a given application. The criteria of usefulness in itself is highly subjective, but even more subjective is the threshold level of EIFOV beyond which the data becomes useless for a given application. In an attempt to become more quantitative in defining resolution requirements, a graph was prepared for each

*NASA/GSFC, 1972, A Report of Advanced Imagers and Scanners Working Group (AISWG) Proceedings, 11-15 December 1972.

application which plots relative value of the SEOS data to the application as a function of EIFOV (see Figure 3).

Separate curves were prepared for bands in the reflective solar region of the spectrum and thermal infrared. There was a tendency among users to resist this effort. Often as a starting point, an almost arbitrary curve was drawn. This "first" plot was used to generate reaction from subsequent reviewers who were asked to agree with it or suggest changes. The curves presented in this report are the iterative products of such a review process.

The relative value of data from a sensor of a given resolution connotes different meanings to different users and in different applications. In some cases, it may mean that with a given resolution only a certain percentage of possible targets can be observed while in another it may mean that all the targets could be observed but with a certain percentage of effectiveness. In any event, one must avoid inferring more than what these curves are intended to represent; a subjective evaluation of the utility of SEOS as a function of its spatial resolution.

Finally, since operation in the thermal infrared imposes considerable complexity in the sensor design,* a judgement as to the absolute necessity of thermal data requirements was made so that one can define which experiments a SEOS without thermal bands can perform. Thus, each application has been thresholded as requiring or not requiring thermal infrared. It should be noted that in many applications, thermal infrared may not be absolutely essential, yet it would contribute highly useful information.

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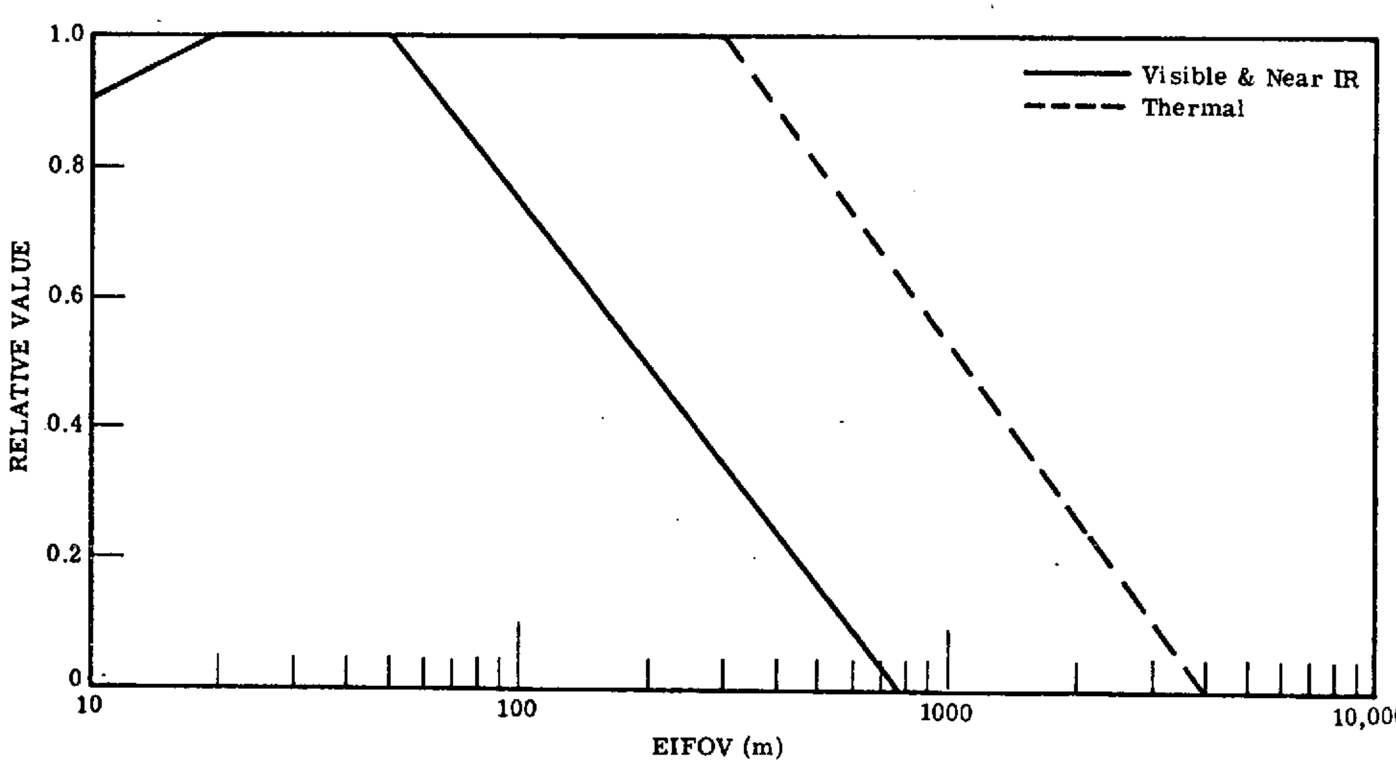
*Detector technology requires that thermal detectors be cooled in order to obtain the desired sensitivity. In addition, it is highly unlikely in the SEOS time frame, that they can be used in the "push-broom" self-scan mode proposed for reflective channels. Thus, a SEOS with thermal bands will require considerably more engineering than a SEOS with a like number of bands but all operating in the reflective solar region.



APPLICATION: Earthquake Prediction

FIGURE 3. SAMPLE GRAPH OF RELATIVE VALUE VERSUS EIFOV

DATA REQUIREMENTS

As noted earlier, data requirements may vary among applications areas and along the user chain in a particular application. Teams were asked to consider all stages involved in implementing actions or defining plans and programs based upon the result of this data collection and interpretation. In particular, data format and the timeliness for specific information (i.e., how long after the observation of a given event or condition are data and/or decisions required). Finally, are ancillary data necessary in successfully using geosynchronous data? For example, are the history of previous meteorological conditions or extended forecasts necessary in assessing flood potential or firefighting plans?

INTERIM ACTIVITIES

In numerous application areas, current models are insufficient to adequately predict response to particular conditions or environmental parameters. In such cases, an interim activity may be necessary to more fully define signatures, spatial or temporal behavior, or predictive models. All teams were asked to evaluate needs in this area and to recommend interim studies, their nature, goals, level and time frame, in order to more effectively utilize an earth synchronous capability in the 1980's. These activities were considered to range from basic theoretical analyses to laboratory and field studies, or those which can be performed with aircraft data, or from low-orbiting spacecraft platforms connected with other programs.

IMPORTANCE/JUSTIFICATION

Each application must be assessed in terms of its social, economic and legislative importance. For example, is the impact strictly local or does it have national or international significance? Both ERIM teams and reviewing experts were asked to attempt to quantify this rather qualitative and often subjective parameter.

Uniqueness

The teams and reviewers were also requested to evaluate the probable capability for meeting application goals with non-geosynchronous data collection, i.e., is the mission uniquely suited to SEOS, or does SEOS represent an optimum means of data collection.

Each mission objective (application) was discussed in detail in written summary reports provided by the various investigation teams. However, in order to establish priorities, compare various system and data collection requirements, and define potential mission profiles, it was necessary to summarize such detailed information into concise charts and tables as shown in Table 9 . It is recognized that this procedure necessarily results in the loss of some generality and the detailed reports are therefore included in Appendices A through F.

5.2 Specific Mission Objectives (Applications)

5.2.1 Agriculture/Forestry/Range Resources

Detection & Assessment of Disease and Insect Damage to Cultivated Crops

World food production is quite obviously tied directly to the health and vigor of major commercial crops. Both disease and insect damage take a heavy toll in yield each year; a toll which could be significantly alleviated by early detection (hence corrective action) of adverse attack. Since many (if not most) damaging agents produce physiological and morphological changes associated with plant-soil-water-energy relations, observation of reflected and emitted electromagnetic radiation provides a key to the early detection of the presence of such damaging agents. Clearly such monitoring must be both repetitive and critically timed with major phenological events associated with a particular crop.

Determination of Optimum Crop Planting Dates

By planting at an appropriate time, when soil moisture and temperature have reached their optimum condition in a given locality, farmers can increase yield by maximum utilization of available water supplies and increased growing time. Natural vegetation communities have been shown to be a precise indicator of such critically timed conditions, and repetitive observation of such natural vegetation and its associated phenological change could markedly increase crop yield.

Phenological Classification of Agricultural Crop Types

Crop-type mapping is an important input to yield forecasting and subsequently to associated agricultural activity and economic stabilization. While numerous techniques are now in use, few make more than nominal use of the time-dimension and crop-specific change patterns associated with phenology. Critically timed multidate observation of foliar changes associated with a specific crop can be used as an additional input for crop-type discrimination. Timely data collection, based upon current growing season conditions, can add an important dimension to crop classification while reducing sampling and processing costs.

Detection and Assessment of Disease and Insect Damage to Forest Species

Effective management of forest productivity requires accurate and timely information on tree vigor, for this is a direct measure of growth. Further, millions of board-feet of valuable timber are lost each year due to the combined effect of disease and insect damage. Ground survey methods to locate and assess attack centers are laborious, expensive and time consuming, while simultaneously effective control and management dictates early detection. Both reflected and emitted radiation changes have been shown to be correlated with various damage vectors and timely repetitive observation from geosynchronous orbit could greatly reduce the cost (while increasing the benefit) of current forest management procedures.

Forest Inventory and Valuation for Multiple-Use Management

Although current forest practices generate gross estimates of forest resources, considerable additional effort is required to determine precise location, vigor and conditions affecting multiple use management of much of the nation's forest resource. Improved identification and mapping can result in improved management decisions and optimum non-conflicting commercial and recreational use, hence benefit. Successful identification of forest species is a difficult remote sensing problem which can be considerably simplified by the addition of phenological information, available from critically timed, repetitive observation.

Evaluation of Range Forage Resources and Grazing Pressure Assessment

The range forage resource is a crop which should be properly harvested just as the more normally recognized commercial agricultural crops. However, unlike the agricultural crop, range forage may be highly variable from year to year, and is critically tied to use. By appropriately timed repetitive observation, not only species type, but plant density assessments can be derived and used to properly regulate grazing pressure. Different forage classes have different phenological patterns and optimum use and proper management depends upon matching the grazing animals use to nutritional level and proper stage of plant maturity.

5.2.2 Land Use Survey and Mapping

Management of Irrigation

Determining the need for an appropriate timing of irrigation can both increase crop yield and maximize the benefits derived from available water supply. A promising method for determining soil moisture (hence, plant moisture) content is the observation of diurnal excursion of soil temperature. This obviously requires short-time interval repetitive observation, perhaps over periods of several days. Additional benefits may be derived from an assessment of the effectiveness of distribution systems and monitoring for leaks.

Wildfire Detection and Monitoring

Wildfires represent a natural disaster causing millions of dollars loss in time and valuable rangeland each year. Obviously, early detection is important in controlling wildfires and continuous monitoring during the fire control operation has been shown to be very valuable in proper allocation of men and equipment. Repetitive scanning of fire prone areas (on a daily basis) could result in the early detection of numerous incipient fires, at a time when proper control procedures could be most effective. Monitoring during the suppression effort is of major importance in delineating the instantaneous perimeter and internal fire details.

Diurnal and Seasonal Variations for Thematic Mapping

Thematic mapping is a generic term covering the collection and presentation of information applicable to numerous fields of earth resource management. However, the unique characteristics of observation from a geosynchronous platform offer new (and otherwise unavailable) information on diurnal variations and sun-angle effects which can be used for more detailed and accurate mapping of earth features. These could increase the ability to discriminate various types of terrain, topography, vegetation, urban areas, etc. Shadows, night lighting patterns, goniometric effects of diurnal temperature changes require critically timed, repetitive observation.

5.2.3 Mineral Resources, Geological, Structural and Landform Survey

Exploration for Geothermal Sources

Geothermal sources offer the potential of cheaper, more pollution free sources of energy than either hydroelectric, hydro-carbon burning or nuclear power sources. Exploration for new sources is important, due to the need for an ever increasing energy output and due to the need to locate sources near the consumer whenever possible. The more obvious sources are readily locateable, however, the more subtle (and probably more numerous and economically more important) sources require careful analysis and repetitive observation. In particular, several diurnal cycles are expected to be required to separate subtle subterranian sources of energy from solar and climatic surface effects.

Monitoring and Prevention of Aeolian Soil Erosion

The destructive effects of wind erosion are very serious, not only in removing rich topsoil but through the abrasive effects of blowing debris, especially sand. Factors influencing wind erosion are soil moisture, surface condition and soil characteristics, as well as current weather predictions. Given adequate knowledge of soil characteristics, available through semi-continuous repetitive observation, corrective action (irrigation, mulching, tillage, etc.) could be taken to alleviate some of the more destructive effects of wind erosion.

Monitoring Water Erosion and Deposition

The degradation of the land surface by shore waves or running water produces various clastic detritus or sediment which is often transported great distances prior to deposition. These processes, particularly such events as storm surges, rampaging streams and broad-scale silting create serious hazards in relatively short time periods. Daily (or even hourly) information on conditions is important for proper land use allocation, flood control measures, disaster relief, and the maintenance of river and coastal waterways.

Monitoring Volcanic Regions

Much effort has gone into the study of the dynamic nature of volcanoes and their related phenomena, such as magma chambers, lava tubes, hot springs, etc. Aerial infrared surveys have contributed to this research of volcanic areas by mapping changes in temperature and temperature patterns in volcanic regions. Besides their exploitation as inexpensive heat sources (e.g., in Iceland), volcanoes may yield clues as to the causes and precursors of some earthquakes. For instance, a correlation between seismic events near an island volcano and solid earth tides has been discovered. It is not unreasonable to expect that temperature changes associated with the rise and fall of magma in the chambers of a volcano (possibly correlated with earth tides or other pressure-inducing events) may be one of the useful inputs for predicting volcanic eruptions, which could save lives in populated areas near volcanoes. A geosynchronous platform is uniquely suited to volcanology studies because surveillance could be made on a daily or twice daily basis over extended periods of time, such as six months to a year.

Prediction of Landslides and Avalanches and Monitoring Subsidence

Landslides and snow avalanches are dangerous phenomena due to their sudden topographic change. These processes are often preceded by more gradual topographic changes such as slumping, a gradual movement of portions of a steeply sloping hillside. Slumping is observable as a change in the location of portions of a landform such as variations in elevation of a particular point. An observation of such topographic changes by monitoring from geosynchronous orbit SEOS may provide early warning of avalanches and landslides.

With increased mining operations, liquid extractions, and numbers of people engaging in outdoor recreational activities (such as skiing), the possible dangers from landslides, avalanches, or dramatic subsidence is increasing. A system capable of predicting these catastrophic events has the primary benefit of preventing or reducing human injury or death.

Diurnal and Seasonal Variations for Geomorphic Survey

High altitude photography permits a continuity of observation not possible with larger scale photographs. Relief is small compared to camera or sensor height and problems of relief displacement virtually disappear. Further, the regional significance of some geologic features is more readily recognized and interpreted in small scale photography. Even the early geomorphologists recognized that the degree of slope, roundness of features or resistence to weathering are characteristic of the materials on which these features developed.

While it is well known that some sun-angles are quite disadvantageous for photographic certain terrain conditions, given sequential observations, these same changes can be put to constructive use in landform interpretation. Variations noted in the diurnal (hence goniometric) reflectance characteristics of different terrain features, particularly in areas of sparse vegetation, can be used to selectively enhance differences in topographic development on differing geologic features.

For example, a series of critically timed observations could lead to topographic relief determination through computer impelemented shadow-enhancement techniques. Such observations could be of significant value in generating or updating base maps, for geologic reconnaissance and for mineral exploration, particularly in remote and inaccessible areas. Sequential, multi-sun-angle observation could well provide information which is unavailable in any single observation.

Diurnal and Seasonal Variations for Lithologic Surveys

Lithologic survey is extremely important to resource management, in guiding appropriate activities of both governmental and industrial organizations. Particularly in developing countries, optimum exploration of available resources is of great importance. In addition, such surveys contribute to an understanding of geologic processes, both current and historic, and may yield information on the location of mineral deposits, ground water anomalies, and earthquake prediction.

There are many regions in North and South America outside the United States which are not geologically mapped. In many of these areas, weather patterns have prevented aircraft and satellite coverage of the ground. Lithologic survey, particularly in wilderness areas, may be considerably advanced through techniques applicable from geosynchronous orbit. For example, such a platform would be uniquely suited to observing silicate reststrahlen bands (caused by intramolecular vibrations) if it carried instrumentation operable in several thermal IR channels. Further, information gained through thermal inertia effects could be used to map lithologic units from spacecraft data. This technique utilizes the thermal response of the earth's surface to diurnal solar illumination variations, from which thermal inertia is calculated. Though this has been applied only to surface exposures of lithologic units, it conceivably could be used to detect underground ore bodies or water reservoirs which are not obvious at the surface. The technique would be even more powerful if used in conjunction with multiple thermal and visible-reflective IR lithologic survey techniques.

Earthquake Prediction

New breakthroughs in theoretical insight related to earthquake phenomena have been made in the past few years, which may lead to a prediction capability. Earthquakes are estimated to be capable of damage on the order of $20 billion in the Southern California area alone. Savings in property damage and lives can be effected by proper action, given sufficient warning time.

Some of the geophysical phenomena identified as precursors to earthquakes include mechanical deformation of the earth's surface, microseismic activity increases, increases in electrical conductivity, and changes in both chemical composition and pressure of groundwater. These latter phenomena have been hypothetically related to dilatancy, whereby rocks under stress undergo a volume expansion caused by the appearance of microcracks and voids in the stressed rocks.

There are several phenomena related to ground water level changes that may be observable from a geosynchronous satellite, besides the temperature differences between ground water and surface materials. One is the change in thermal inertia of the soil due to a higher groundwater level, i.e., the temperature response to diurnal illumination variations may be changed. Another potential observable is a variation in dielectric constant, possibly detectable by radar and caused by soil moisture changes related to varying groundwater levels.

Successful monitoring of earthquake-prone areas will require repetitive to near continuous observation, and an ability to react in a short time frame is necessary to saving human life.

5.2.4 Water Resources

Flood Prediction, Survey and Damage Assessment

A geosynchronous satellite may have utility in the prediction (or early warning) of flash floods caused by spring snow-melt or heavy localized rainfall. The former is somewhat predictable and trated separately in the next section, while the latter can be highly unpredictable, severe, and (by definition) associated with an obscuring cloud over timely observations of soil moisture, reservoir capacity, stream flow, soil type, vegetation cover, etc., can provide essential information on impending flood conditions.

Flood waters themselves are readily observable and provide important information for future control measures, relief activities and damage assessment. The capability to observe at the earliest opportunity offered by clearing conditions is unique to synchronous orbit.

Monitoring Extent, Distribution and Change of Snow Cover

Accurate monitoring of snow accumulation and snow volume over large areas, such as the Columbia River watershed, could permit increased accuracy in both short-term and long-term predictions of streamflow. Improved accuracy of prediction would produce better allocation and control of the available water supply for power development, domestic and industrial water supply, and irrigation.

Information on snow cover area can be related to other significant variables, such as time distribution of water stored in the snowpack, energy balance over regional areas, snowline altitude, and snow depth as a function of altitude. Detailed studies indicate that with repeated coverage at 6-hour intervals, the probability of obtaining a clear look at the snow-covered areas in the Columbia River Basin is high enough to be able to observe each major new accretion of snow during the winter months and to make adequate observations during the critical snowmelt period. SEOS would provide the continuity of coverage required.

For monitoring of snow volume, the desired information is total equivalent amount of liquid water and its distribution throughout the watershed. SEOS could contribute to this process by mapping the extent of snow cover and the rate at which this snow cover disappears during the spring thaw. Soil moisture content can be determined by measuring of diurnal temperature excursions for those areas where heavy vegetation cover is not present. Thermal mapping could also aid in estimation of snow melting rate and evaporation from reservoirs.

Monitoring Lake and Sea Ice for Navigation

Lake ice and sea ice are very dynamic physical features within the spatial location and extent of leads and polynyas of open water, brash ice, refrozen leads and ice floes of different thicknesses changing with variations of wind, temperature, currents and other parameters. Knowledge of the location and patterns of movement or change of these features is very important for shipping, particularly in extending the navigation season. This information may be utilized to recommend favorable navigational courses for lake vessels through leads and areas of thin ice, for increased understanding of ice processes for model development for accurate forecasting of freeze-up and break-up times and movement of ice floes and placement of devices used in the extension of the navigation season such as bubbler systems, ice booms, and optimum deployment of ice breakers.

In areas of frequent cloud cover (such as portions of the Great Lakes, where 90% of the days in December are either cloudy or partly cloudy) observation from a geostationary platform provides the distinct advantage of monitoring during infrequent clear periods.

Better understanding of ice processes with subsequent modeling and the rapid availability of imagery for navigation instructions in areas such as the Great Lakes and margins of the arctic and antarctic ice packs can have a significant effect to many countries. An extension of the navigation season can have military and scientific benefits and considerable economic benefits.

Monitoring and Analysis of Lake Dynamics

The dynamics of lake currents, upwelling, thermal bars, and other phenomena related to the motion of water masses within lakes accounts for beach erosion, unwanted pollution distribution, and contributes to flooding potential. The timely measurement of associated phenomena would allow steps to be taken to reduce or eliminate these adverse effects. Knowledge gained from such measurements could be used to design and build structures to modify current patterns and reduce damage to shorelines caused by erosion and deposition, and to place intake and discharge points for power plants and city water systems more optimally. A continuous series of satellite observations would provide information not now available to designers and managers and thus would lead to the development of measures for the alleviation of problem areas.

Major events occur on a time-scale of 2-3 days, and could be charted by periodic observations every 6 to 8 hours. Nighttime observations should also be made using a thermal channel. The control of the distribution of unwanted water pollutants alone has immeasurable benefits, including the improvement in the quality of living.

5.2.5 Marine Resources and Ocean Surveys

Estuarine Dynamics and Pollution Dispersal

Estuarine areas are among the biologically most active portions of the marine environment and provide food and/or an indispensable habitat during all or portions of the life cycles of many commercially important fish and shellfish. The complexity and variety of estuarine use is great, and also includes categories such as recreation, wildlife habitat, extraction industries, waste assimilation, land reclamation, and transportation.

Estuaries have both economic and social importance and estuarine activities are highly interrelated due to the use of a common set of natural resources. In addition, the estuarine environment in many areas is rapidly changing due to the mounting intensity of estuarine use. The trend toward increasing multiple-use and the resultant stress on the estuarine ecosystem may be expected to continue.

The knowledge of estuarine circulation dynamics and the resulting dispersal of suspended and dissolved substances that are both naturally and culturally introduced is fragmentary at best. Timely information collected from geosynchronous orbit would make possible the effective design and regulation of municipal and industrial activities, insure the future of shelling and fishing industries, preserve wildlife and scenic amenities, and ultimately aid in obtaining maximum use of estuarine resources, not only in the United States but throughout the world.

Position and movement of thermal discontinuities, current direction and velocity, upwellings, sediment load, spectral differences and algal blooms are all parameters which change markedly over short time intervals. Thus, the capability for repetitive observation during cloud free periods is essential to proper analysis and management of this important source.

Detection and Mapping of Shoal Areas

The need for updating navigation charts to remove doubtful hydrographic data was identified as a major problem at the Fourth Session of the International Oceanographic Committee meeting in 1964. The International Hydrographic Office has expressed concern over the status of shipping charts around the world, many of which cannot be updated due to lack of technical resources on the part of some countries.

Location information is one of the most likely sources for ambiguity on shipping charts. Positions of many doubtful shoals are known only approximately. The same shoal may have been reported with inaccurate geographical coordinates by different ships. Storms bring rapid changes so that even recent maps may be in error due to shifting sand bars and coastline readjustments. If only surface ships are used for hydrographic surveys, a long slow process is involved and the limitations of sampling procedures affect the accuracy of the work.

One method of detecting shoal areas and measurement of water depth takes advantage of the fact that wavelength and direction of water waves and swells are influenced by bottom conditions where depth is not greater than about half the wavelength. Analysis of such wave refraction has been demonstrated in one frame of Apollo 7 imagery indicating both the feasibility of the approach and the critical timing necessary to obtain appropriate imagery.

Opportunities to observe suitable wave patterns may occur at any season of the year, but the useful duration at a given location may amount to a day or less. During this critical period, observation from geosynchronous orbit could be used for repeated coverage at hourly intervals for perhaps 6 to 12 hours.

Potential benefits include the reduction in economic loss due to shipping accidents, due to delay when ships are idle or due to longer routing around suspected shoal areas, as well as the obvious savings in human life and environmental degradation.

Detection and Monitoring Development and Movement of Colored Water Masses (Plankton)

Algal "blooms" often cause massive fish kills, harmful to commercial fisheries and can affect tourism and health as the dead fish drift onto beaches. The exact cause of the red tide is still unknown but is associated with excessive nutrients from surface runoff. Once started, these "blooms" can extend over many square miles of the ocean and can last several weeks. Phytoplankton and zooplankton are cometimes in such abundance, particularly in nutrient rich waters, that they present a possible health hazard.

The red tide occurs randomly throughout the year and generally lasts from several days to several weeks. High concentrations of plankton may be continuous features of varied intensity in a given location or may occur at random times and locations. Development of effective control techniques will require data on demand, with returns in 2 to 12 hours subsequent to a "bloom" detection.

The capability to provide a short term periodical synoptic coverage of an area of plankton concentration is essential to an understanding of such a dynamic situation. A geosynchronous platform is perhaps the most practical and economical sensor for this application and would, in addition, provide the valuable capability for monitoring targets of opportunity.

Monitoring and Analysis of Ocean Dynamics

Contamination of the oceans by oil and other forms of pollution is now widespread, and the need for regulation is becoming apparent. Knowledge of circulation patterns in the oceans is required to formulate regulations regarding the dumping of pollutants and a means of monitoring the oceans for pollution is needed to enforce these regulations. The size of the areas involved and the necessity for continuous observation make the capabilities of a geosynchronous platform ideally suited to this application. Examples of some oceanic processes have been previously observed with low altitude satellites but the dynamic conditions of oceanographic variables could be more properly monitored from a stationary platform.

Finally, ocean currents have an important influence on the climate (e.g., the link between the Gulf Stream and the weather in the wine-producing provinces of France). Closer observation of ocean circulation patterns using SEOS could therefore have important economic and social benefits in this connection.

Satellites have already proved valuable in oceanographic studies, but their usefulness for observing and monitoring dynamic phenomena is limited by their sporadic coverage. This limitation would be effectively removed by a stationary satellite like SEOS.

Detecting and Monitoring Fish Location and Movement

A number of characteristics observable from space may indicate the probable location of fish. These include sea surface temperature, water color (an indicator of various nutrients and of plankton upon which fish feed), clarity, turbidity, salinity, and bioluminescence. From these observable differences, it is also possible to detect such large scale dynamic features as upwellings, tidal changes, and estuarine circulation which have a bearing on fish concentrations.

If fishing vessels could be observed with reasonable continuity, this could be of value in a program for international regulation of fisheries. Patterns of dynamic features such as tides and estuarine circulation will change materially during intervals as short as one day while commercial fishing activity occurs throughout the year. Methods of improving the efficiency with which concentrations of fish can be located would reduce the labor and operating costs for a given size of catch. The ability of a geosynchronous satellite to observe large areas of ocean would allow the application of fish-finding methods to a sizable fraction of the world's fishing industry.

Detection of the probable location of a commercially significant fish concentration is information which must be acted on in a relatively short period of time. Delays of more than a few hours may degrade the usefulness of such information. Geosynchronous observation offers the possibility of both critical timing and of repeated observation whereas low altitude satellites permit observation only at infrequent and inflexible intervals.

Detecting and Monitoring Iceberg Hazards

During a year an estimated 10,000 - 15,000 large icebergs calve from the ice sheets and outlet glaciers of Greenland and Baffin Island. From less than 20 to over 1,000 of these icebergs eventually drift on the Laborador Current into the North Atlantic shipping channels south of Newfoundland. The bergs can begin their existence as several square mile areas and will eventually dissipate. These features can be observed in visible bands, as thermal anomalies, or on radar imagery.

For shipping safety and navigation control, data on the presence, location, and movement of these bergs should be available as soon as possible, with a delay of 4-6 hours being reasonable and a maximum of 24 hours.

The present methodology utilized by the International Ice Patrol (IIP) has been quite successful in preventing losses. However, a geosynchronous observation would provide additional capabilities which could increase the efficiency of the IIP while reducing operation costs. These capabilities include a large synoptic view, use of night or cloud penetration sensors, and observation on demand, through breaks in cloud cover or during fog free periods.

5.2.6 Environment

Detecting and Monitoring Thermal Water Pollutants

Documentation of existing thermal conditions in water bodies, particularly nearshore areas of large lakes and oceans, is a necessary prerequisite for water modeling and for planning municipal, industrial, and recreational uses of water bodies. The observables are intrusions of water bodies of different temperatures from cooling water discharges and tributary streams. These intrusions can be observed in different circulation patterns under varied wind speeds, directions, and water temperatures. Although the processes involved are continuous, large variations can occur in very short time intervals.

A geosynchronous satellite could perform several important functions in observing such processes. For example, it could continuously monitor selected sites for any sudden changes in thermal conditions, provide records of existing thermal conditions as a basis of comparison to later developments, as well as intensively monitor specific areas for short periods under different conditions to provide data necessary for model development.

The ability of SEOS to provide repeated large scale imagery of an area at short time intervals is extremely valuable for a dynamic system. The added ability to take observations on demand in cloud free conditions increase the uniqueness of SEOS.

Detecting and Monitoring Water-Suspended Solid Pollutants

As the production of waste material increases, larger disposal areas are sought and, simultaneously, more concentrated disposals occur. Further, uncontrolled use of water bodies as a disposal area may have serious health, esthetic, and economic consequences. An example of the significance to public health of sewage sludge (even when dumped in deep sea water) is the possible contamination of surf clams which may later be harvested for human consumption. Shellfish are also capable of concentrating and holding bacteria, viruses, and toxic substances that they ingest from their marine environment. In turn, they can transmit these concentrations to consumers of the shellfish. To aid in this and other water pollutant controls, more information on the dynamics of pollution and a monitoring system to assure dumping in areas not destructive to fisheries, recreation areas, and public water supplies are needed.

Suspended solids diffuse in water from their source or sources under the influence of water currents and wind direction and velocity. The pattern of diffusion is determined by changing hydrologic and meteorological parameters and the spatial extent of such effluents is highly variable. Thus, both critically timed and repetitive observation is required to effectively monitor potentially adverse environmental effects. Data collected from geosynchronous satellite may be used to document authorized discharges and to ascertain compliance in location and amount, to document the dynamic nature of the buildup and movement of these effluents, to aid in model development, to detect and control illegal discharges, and to provide information for planning and management decisions. Such information should be available at six hour intervals for extended periods to provide required information on circulation patterns under different meteorological and hydrological parameters.

Detecting and Monitoring Oil Pollution

The expanding energy needs of an industrialized society have served as a stimulus for increased oil exploration and oil field development. The expansion of oil exploration and production into tidal and coastal regions has increased the likelihood of major oil spills. Additionally, the fact that most of the world's oil production is transported in large tankers to serve the markets of the world, creates a very real potential for large scale oil spills. Oil pollution can result from leakage of offshore wells, intentional dumping by ships, breaking of pipelines, and contamination of industrial discharges as well as due to accidents of large oil tankers. From these sources, the oil spreads out as a film on the water surface. The spatial and temporal extent of these films are dependent upon the amount of oil spilled, wind and current conditions, and the efforts of man in controlling them.

The well-publicized Torrey Canyon, Ocean Eagle, and Santa Barbara episodes exemplify the magnitude of the problem. Serious damage to waterfowl and aquatic life, as well as extensive damage to beaches, can occur from such accidents despite attempts to contain the oil spills. As more and more advances are made in the technology of containing and dispersing oil slicks, the major concern becomes one of rapid location of oil slicks so that corrective measures can be taken before serious damage is done.

Control of the problem requires a rapid and flexible surveillance system for enforcement purposes and the effective control and spill cleanup. A geosynchronous satellite could provide such surveillance, which would have high esthetic, ecological and economic returns.

Analysis of Undesirable Heat Islands in Urban Areas

An analysis of the urban climate in terms of energy systems gives quantitative insight into the disposal of solar energy by distinctive urban surfaces. Streets between rows of buildings are known to become "thermal canyons." A study of the thermal cavity structure of large cities may suggest that a variety of building heights along a given street is preferable to the common canyon structure which interferes with ventilating winds, creating problems of excess temperature and stagnation of air.

Proper spacing of high-rise buildings can reduce this interference, improve the temperature environment, and reduce the collection of atmospheric pollutants. Removing these irritant sources improves working efficiency and reduces unrest which can result in rioting. Measurement of conditions of net radiation may also suggest the most effective location for greenbelts and open spaces in a particular city situation.

A lack of consideration of the factors affecting urban-regional climates has allowed the development of one of the undesirable features of the urban environment. Repetitive synoptic radiation maps will enable governments to assess present conditions and replace aimless drift with wisely planned change. Increased attention to these factors can thus have a high social value.

A systematic and controlled study of the urban climate environment requires critically timed and repetitive observation through both diurnal and seasonal changes. A geosynchronous satellite offers an ideal platform for such data collection.

5.3 Review Process

The mission objectives (applications) outlined above have been reviewed by a number of specialists, recognized expert in their respective earth-science disciplines. While the specific details described here (and in more detail in the Appendices of this report) are the responsibility of the ERIM disciplinary teams, reviewer's comments and suggestions have been incorporated as far as practical. However, it should be explicitly noted that individual recommendations or instrumentation and observation requirements are not directly attributable to a specific reviewer or user expert.

The authors and ERIM disciplinary teams wish to acknowledge and express their appreciation for the helpful discussions, comments, and suggestions of those reviewers listed in Appendix H.

5.4 Application Prioritization and Rationale

In order to quantitatively assess instrument or observation requirements and mission scenarios in the presence of numerous competing, and perhaps conflicting, objectives (applications), some attempt to prioritize the various applications listed in Table 8 is required. Obviously such an attempt would be, at best, subjective. In this section, a model for prioritizing the applications is described and used to rank order the experiments. The results of this prioritization of the 32 experiments are given in Table 10.

Candidate applications for SEOS can be used to justify the need for SEOS. One must, however, establish which of the experiments have the higher priority in order to determine a mission profile. Without this, one cannot determine that SEOS has a role in NASA's earth observation program, i.e., is it cost effective? For example, it may take six SEOS satellites to conduct a limited set of application demonstrations and the cost for this may be equivalent to launching a large enough number of ERTS satellites to perform most of the tasks conceived for SEOS.

TABLE 10. SEOS APPLICATIONS
(Listed in Order of Priority)

Priority	(Appendix No.)
1	Detecting & Monitoring of Water-Suspended Solid Pollutants (F2)
2	Estuarine Dynamics and Pollution Dispersal (E1)
3	Monitoring Extent, Distribution & Change of Snow Cover (D2)
4	Monitoring Volcanic Regions (C4)
5	Detecting & Monitoring Development & Movement of Colored Water Masses (Plankton) (E3)
6	Detecting & Monitoring Fish Location & Movement (E5)
7	Ocean Dynamics (E4)
8	Detection & Assessment of Disease & Insect Damage to Forest Species (A4)
9	Forest Inventory & Valuation of Multiple-Use Management (A5)
10	Evaluation of Range Forage Resources & Grazing Pressure Assessment (A6)
11	Management of Irrigation (B1)
12	Detecting & Monitoring Oil Pollution (F3)
13	Diurnal & Seasonal Variations for Lithologic Survey (C7)
14	Monitoring & Analysis of Lake Dynamics (D4)
15	Wildfire Monitoring (B3)
16	Flood Prediction, Survey & Damage Assessment (D1)
17	Monitoring Water Erosion & Deposition (C3)
18	Diurnal & Seasonal Variations for Thematic Mapping (B4)
19	Monitoring and Prevention of Aeolian Soil Erosion (C2)
20	Detection & Assessment of Disease & Insect Damage to Cultivated Crops (A1)
21	Determination of Optimum Crop Planting Dates (A2)
22	Earthquake Prediction (C8)
23	Exploration of Geothermal Sources (C1)
24	Monitoring Lake & Sea Ice for Navigation (D3)
25	Diurnal & Seasonal Variations for Geomorphological Survey (C6)
26	Wildfire Detection (B2)
27	Detection & Mapping of Shoal Areas (E2)
28	Phenological Classification of Agricultural Crop Types (A3)
29	Detecting & Monitoring Thermal Water Pollutants (F1)
30	Analysis of Undesirable Heat Islands in Urban Areas (F4)
31	Prediction of Landslides & Avalanches & Monitoring Subsidence (C5)
32	Detecting & Monitoring Iceberg Hazards (E6)

A simple model was conceived to prioritize the candidate applications. After considerable deliberation, it was judged that three independent factors should be used as criteria for determining a given application. These were:

(1) the importance or value of the application,

(2) the ability of SEOS to perform the experiment, and

(3) the uniqueness of the data collection to SEOS.

The first criterion, value, was considered to be a combination of dollar value and legislative requirement. Initially, social value was also included but it was considered to be redundant with legislative requirement (the pressures of social issues result ultimately in legislative action). The second criterion, SEOS ability, was considered to be a combination of the ability of a sensor at synchronous altitudes to make the measurements with suitable resolution and sensitivity and the feasibility that given the measurements, the application will be successful. The last criterion, uniqueness, was based on how important is timely information to realization of the objectives of the application and what are the consequences of missed or untimely data. It should be noted that implicit in timeliness is the location and areal extent of the target, e.g., SEOS may be required to obtain timely, damage assessment of an extensive quake in Guatemala but one may prefer to use an aircraft for a small tremor in the San Francisco area.

Given a value for each of these criteria, the prioritization model used the product of these values as a score and the applications were ranked according to this score. The rationale for using the product can be best visualized with the aid of Figure 4 . Consider each criterion as an axis in three dimensional space. The application which has the largest volume has the highest priority. This model is valid at least for the extremes as it goes to zero when any one of the criteria is zero. It also makes sense at mid-ranges. Given two applications with the same timeliness, one with a high value but low probability that SEOS can do it successfully may have the same priority as one with a low value but readily achieved by SEOS.

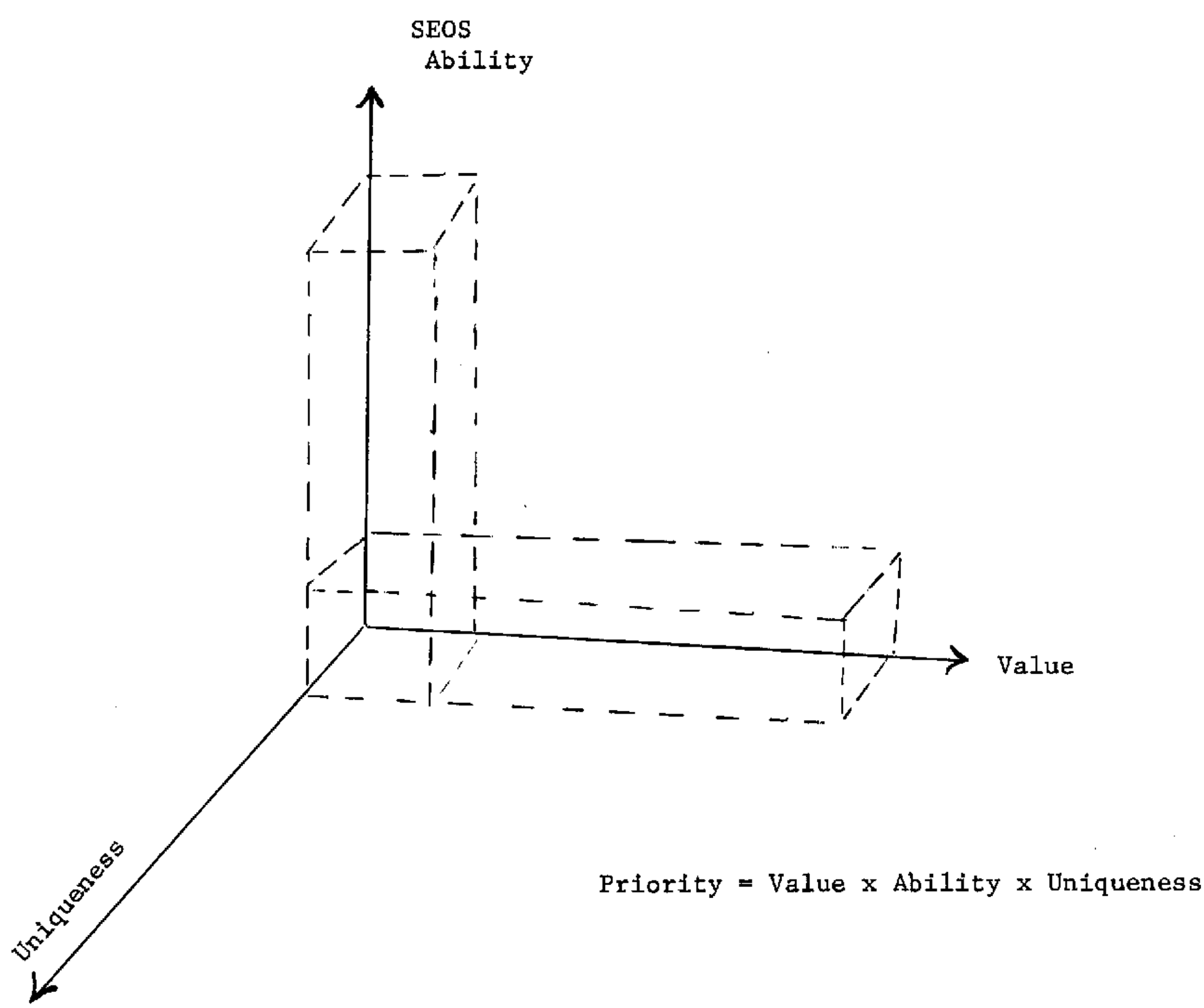


FIGURE 4. Prioritization Model Using Product of Three Criteria Rankings

Having established these primary criteria, all applications were ranked according to each criteria independently, by four different persons, each familiar with the overall mission goals, projected system capabilities, and the literature and review processes available in each disciplinary area. These persons assigned a value of 1 to 10 to each criteria, 10 being the most favorable for SEOS. As pointed out earlier, these values are subjective and it is recognized that the individual reader may take an exception to a specific ranking (or rankings). No pretense is made as to the accuracy of the ranking, but the approach is felt to be sufficient for present purposes, namely that of establishing which applications are most likely to be investigated by SEOS. This in turn is used to establish sensor and system requirements.

The scores for evaluating the criteria of SEOS ability and value were forced to be uniformly distributed between 1 and 10. For the criterion of uniqueness to SEOS, these numbers were allowed a more limited range (4 to 10) inasmuch as all the experiments had been screened on the basis that they require the unique feature of SEOS's timeliness of observation. Thus, the dominant factors in determining priority were value and SEOS ability.

The rankings in each criterion for all the applications are presented in Table 11. The applications are listed in descending order of priority. Also presented in the right hand column of Table 11 on a scale of 1 to 5 is the feasibility status of the application. This factor together with the performance capability of the SEOS sensor makes up the criterion of SEOS ability. This parameter is listed separately because it is felt that too often it is overlooked in stating the potential of remote sensing from space. The scoring suggested for assessing feasibility is:

(1) Based solely on hypothesis
(2) Based on proven theory
(3) Measured in the laboratory
(4) Measured in the field
(5) Measured with remote sensors.

TABLE 11

SEOS APPLICATIONS

SEOS Ability	Value	Uniqueness to SEOS	Relative Priority	Appendix Number		Feasibility
10	10	10	1000	F2	Detecting Water-Suspended Solid Pollutants	5
8	10	10	800	E1	Estuarine Dynamics & Pollution Dispersal	5
10	8	8	640	D2	Monitoring Extent & Change of Snow Cover	5
10	5	10	500	C4	Monitoring Volcanic Regions	5
10	6	8	480	E3	Detecting Development & Movement of Colored Water Masses (Plankton)	5
5	10	9	450	E5	Detecting Fish Location & Movement	3
6	9	8	432	E4	Ocean Dynamics	5
6	7	10	420	A4	Detection of Disease & Insect Damage to Forest Species	5
7	7	7	343	A5	Forest Inventory & Valuation of Multiple-Use Management	4
6	7	8	336	A6	Evaluation of Range Forage Resources & Grazing Pressure Assessment	3
5	8	8	320	B1	Management of Irrigation	4
5	6	10	300	F3	Detecting & Monitoring Oil Pollution	5
8	4	9	288	C7	Diurnal & Seasonal Variations for Lithologic Survey	4
4	9	8	288	D4	Monitoring & Analysis of Lake Dynamics	3
4	7	10	280	B3	Wildfire Monitoring	2
3	9	10	270	D1	Flood Prediction, Survey & Damage Assessment	3
6	6	7	252	C3	Monitoring Water Erosion & Deposition	4
8	3	10	240	B4	Diurnal & Seasonal Variations for Thematic Mapping	4
4	6	9	216	C2	Monitoring & Prevention of Aeolian Soil Erosion	2
2	10	10	200	A1	Detection of Disease & Insect Damage to Cultivated Crops	5
8	3	8	192	A2	Determination of Optimum Crop Planting Dates	4
2	8	8	128	C8	Earthquake Prediction	1
4	3	10	120	C1	Exploration of Geothermal Sources	2
5	4	5	100	D3	Monitoring Lake & Sea Ice for Navigation	5
2	4	10	80	C6	Diurnal & Seasonal Variations for Geomorphological Survey	1
1	7	10	70	B2	Wildfire Detection	3
6	1	9	54	E2	Detection & Mapping of Shoal Areas	4
3	3	6	54	A3	Phenological Classification of Agricultural Crop Types	2
1	6	8	48	F1	Detecting & Monitoring Thermal Water Pollutants	5
1	5	9	45	F4	Analysis of Undesirable Heat Islands in Urban Areas	1
1	5	8	40	C5	Prediction of Landslides & Avalanches	1
3	2	2	12	E6	Detecting & Monitoring Iceberg Hazards	4

The above scoring system served only as a general guideline for assessing feasibility status and considerable latitude was taken in the final assignment of a score. For example, a particular phenomenon which had been observed with remote sensors may be given a score less than 5 if it were judged that there is some doubt that it could be performed consistently from SEOS.

To test the sensitivity of the ranking to other ways of combining the data, the criteria scores were summed rather than multiplied. The rank order based on the sum pretty much followed that obtained from the product, but there was considerably less spread among the scores produced by summing. The top eight of the two priority lists were unchanged and both methods of ranking had the same top twenty applications. This is not surprising as the top priority (large products) means both multipliers are large and thus the sum would be large also. One would expect, however, the lower priority applications to have a more random relationship. A sum which is 10 could have products of 9(9 x 1), 16(8 x 2), 21(3 x 7), 24(4 x 6) and 25(5 x 5). Regardless of how they are combined, the dominant factor influencing the ranking order is the magnitude assigned to value or ability.

6.0 SEOS REQUIREMENTS

6.1 Typical SEOS Capability at a Given Resolution

The applications discussed in Section 5 can be further refined to determine SEOS sensor and system requirements. As part of each application description in Appendices A through F, a graphical estimate of the potential yield of an experiment is given as a function of the sensor resolution (effective field of view). Separate curves are presented for the solar reflective wavelengths and the thermal infrared.

In order to determine what applications a SEOS with a given capability can perform, some criterion must be established to quantify the resolution. For the discussion which follows, the resolution required for each application was the 50% point on the resolution curve. A further decision had to be made concerning the relative value of the wavelength bands of operation. Since the diffraction limit of the thermal infrared is orders of magnitude larger than the visible bands and the infrared detectors require cooling, it was decided to single out two spectral regions of operation, solar reflective and thermal infrared, and inquire as to the absolute necessity of these bands to the success of the experiment. These data were then used to produce two tables. Table 12 lists those applications which could be performed with a SEOS without a thermal infrared channel and a resolution of 100 m in the reflective bands. This restriction on the sensor reduces the number of SEOS experiments from 32 to 12. Of these 12 applications, 6 are from the upper 10 of the original list. Table 13 presents those applications which could be performed with a thermal infrared resolution of 600 m and a reflective resolution of 100 m. This listing yields 22 applications with all of the top 10 experiments from the original list. These top 10 experiments were then analyzed to determine if the time line for conducting them is reasonable. In this regard, it should be explicitly noted that the time line and overall mission scenario is, in general, somewhat affected by the precise experiments selected for this analysis. However, the 10 applications selected as having the highest priority are considered to be statistically representative of all applications investigated in this study, and a time

TABLE 12

SEOS APPLICATIONS WHICH CAN BE PERFORMED
WITH 100 M RESOLUTION IN REFLECTIVE CHANNELS,
NO THERMAL INFRARED

Application Priority		(Appendix No.)
1	Detecting & Monitoring of Water-Suspended Solid Pollutants	(F2)
2	Estuarine Dynamics and Pollution Dispersal	(E1)
3	Monitoring Extent, Distribution & Change of Snow Cover	(D2)
5	Detecting & Monitoring Development & Movement of Colored Water Masses (Plankton)	(E3)
8	Detection & Assessment of Disease & Insect Damage to Forest Species	(A4)
9	Forest Inventory & Valuation for Multiple-Use Management	(A5)
16	Flood Prediction, Survey & Damage Assessment	(D1)
17	Monitoring Water Erosion & Deposition	(C3)
25	Diurnal & Seasonal Variations for Geomorphological Survey	(C6)
27	Detection & Mapping of Shoal Areas	(E2)
28	Phenological Classification of Agricultural Crop Types	(A3)
31	Prediction of Landslides & Avalanches & Monitoring Subsidence	(C5)

TABLE 13

SEOS APPLICATIONS WHICH CAN BE PERFORMED
WITH 100 M RESOLUTION IN REFLECTIVE CHANNELS
AND 600 M RESOLUTION IN THE THERMAL INFRARED

Application Priority		(Appendix No.)
1	Detecting & Monitoring of Water-Suspended Solid Pollutants	(F2)
2	Estuarine Dynamics and Pollution Dispersal	(E1)
3	Monitoring Extent, Distribution & Change of Snow Cover	(D2)
4	Monitoring Volcanic Regions	(C4)
5	Detecting & Monitoring Development & Movement of Colored Water Masses (Plankton)	(E3)
6	Detecting & Monitoring Fish Location & Movement	(E5)
7	Ocean Dynamics	(E4)
8	Detection & Assessment of Disease & Insect Damage to Forest Species	(A4)
9	Forest Inventory & Valuation of Multiple-Use Management	(A5)
10	Evaluation of Range Forage Resources & Grazing Pressure Assessment	(A6)
13	Diurnal & Seasonal Variations for Lithologic Survey	(C7)
16	Flood Prediction, Survey & Damage Assessment	(D1)
17	Monitoring Water Erosion & Deposition	(C3)
18	Diurnal & Seasonal Variations for Thematic Mapping	(B4)
19	Monitoring and Prevention of Aeolian Soil Erosion	(C2)
21	Determination of Optimum Crop Planting Dates	(A2)
22	Earthquake Prediction	(C8)
23	Exploration for Geothermal Sources	(C1)
25	Diurnal & Seasonal Variations for Geomorphological Survey	(C6)
27	Detection & mapping of Shoal Areas	(E2)
28	Phenological Classification of Agricultural Crop Types	(A3)
31	Prediction of Landslides & Avalanches & Monitoring Subsidence	(C5)

line developed for those experiments is considered to represent a valid estimate of demands and requirements for a SEOS mission.

To see if SEOS performance requirements are biased with priority (e.g., does high priority require high spatial resolution), the spatial resolution requirements were analyzed in the following manner. The plots of spatial resolution vs relative value for all applications were summed with and without weighting their relative values as determined by their priority ranking. Table 14 presents these results. Column two of Table 14 gives the sum of all application curves at the EIFOV values given in column one. In this column, all applications are assumed to have equal merit. Column three gives the sums of each curve weighted according to its priority ranking, i.e., the priority ranking numbers given in Table 11. In generating the numbers in column three, the highest priority application (Detecting and Monitoring of Water-Suspended Solid Pollutants) was weighted 1000 while the lowest priority application (Detecting and Monitoring Iceberg Hazards) carried a weighting factor of 12. The numbers in columns two and three were normalized to the 10 meter EIFOV value and are presented in columns four and five of Table 14. These results are plotted in Figure 5. In these plots of the overall effectiveness of SEOS as a function of EIFOV, the solid line assumes all applications have the same relative merit and the dashed line weights the applications according to their relative ranking. From these curves, one might conclude that resolution requirements are independent of priority ranking.

Before proceeding with time lining the experiments, the effects of mission accomplishments with reduced resolution in the reflective channels should be analyzed and commented upon. To begin with, the resolution requirements were undoubtedly influenced by the knowledge that diffraction limits the ultimate capability of SEOS. This factor is obvious when one observes that in most applications which require both reflective and thermal infrared, the resolution requirement for the thermal infrared is less than that for the reflective channel. This is justified (or rationalized) in that low spatial resolution of data of one nature is found to be extremely useful

TABLE 14

RELATIVE EFFECTIVENESS OF SEOS FOR PERFORMING ALL APPLICATIONS

(For Solar Reflective Bands Only)

EIFOV (Meters)	Unweighted Sum of Applications	Weighted Sum of Applications	Unweighted Effectiveness (Relative to 10M)	Weighted Effectiveness (Relative to 10M)
10	30	8982	1.0	1.0
50	28.5	8585	.95	.95
100	24.0	7180	.80	.80
200	16.8	5029	.56	.56
400	9	2135	.30	.24
800	4	1352	.13	.15

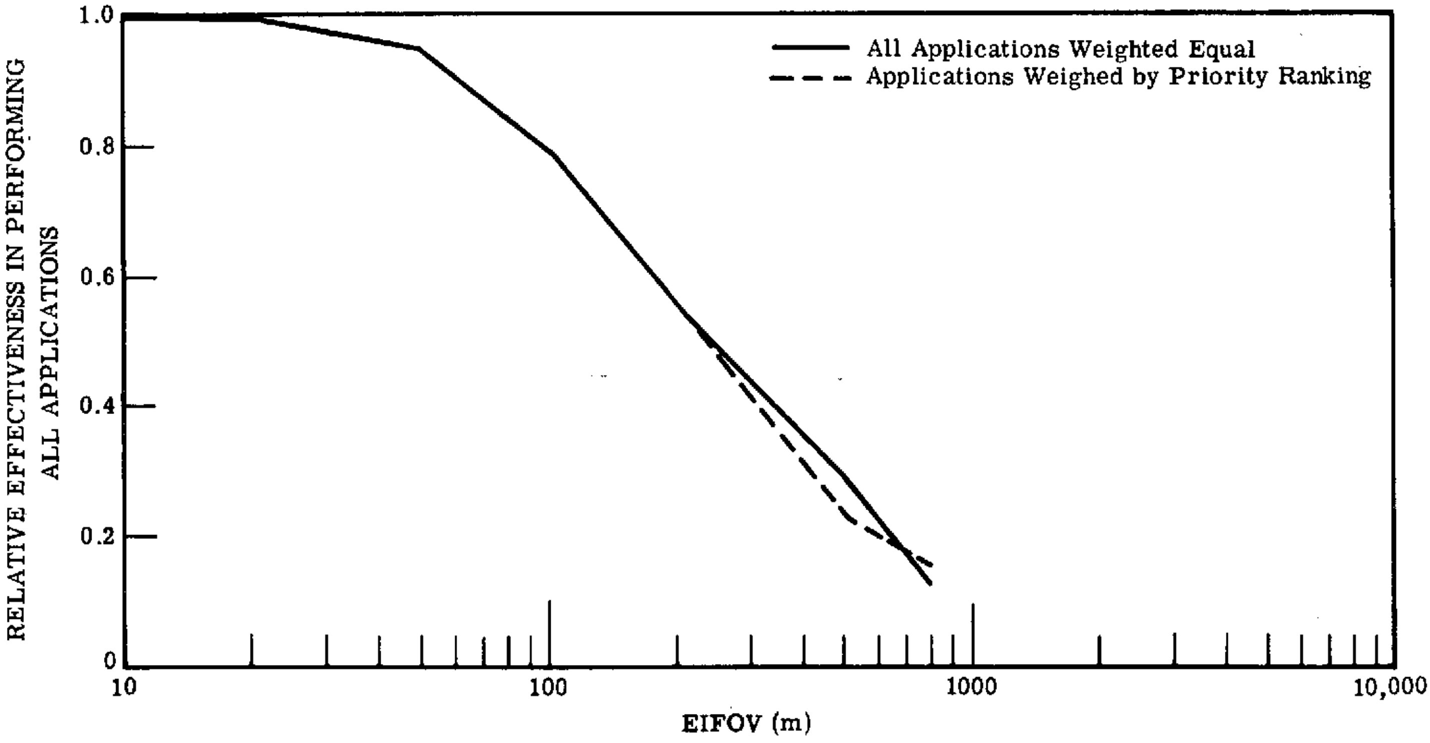


FIGURE 5. RELATIVE SEOS EFFECTIVENESS VERSUS EIFOV

when used in conjunction with high resolution data of another nature. For example, quantitative thermal data concerning extent and run-off of small rivers may not be obtainable directly as inputs for modeling estuarine dynamics. Thermal infrared data on the heat budget and circulation patterns in the bay together with data on the location and extent of the small rivers will permit determination of their contribution to the overall situation.

If one were to back off the resolution requirement for the reflective channel from 100 to 200 m, only four of the applications listed in Table 13 cannot be performed. Of these four, only two are in the top ten category (Fish Location and Damage to Forest Species). While the price for lowering the resolution a factor of two appears to be a small reduction in sensor capability, it is not recommended at this time for the following reason. The curves relating value to an application with sensor resolution cannot be considered to be hard and fast. Further, we have used the 50% point on this curve to define acceptable resolution. When the resolution is changed to 200 m, one does not just drop two experiments. Rather the relative value for each application is reduced.

Ground Rules for Determining Data Collection Profile

In order to develop the time required to conduct the top ten experiments (application demonstration), some value of sensor system capability must be assumed. An earlier study (NASA/GSFC, 1971) showed that resolution of 200 m in the reflective channels and 1.5 km in the thermal infrared was feasible. Analysis of the swath width, scan rates, and number of detector elements shows that it is not unreasonable to improve on this resolution based on the state of the art technology. For this study, we assume the following sensor performance.*

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*While these performance figures are feasible, the engineering design to obtain them remains to be done. One obvious problem would be how to combine a scanning array in the thermal infrared with a pushbroom array in the reflective region to simultaneously collect data from a scene.

Swath Width:	100 to 200 km (dependent upon the number of detector elements)
Resolution:	100 m in reflective channels 600 m in thermal infrared
Sensitivity:	$NE\Delta\rho < 0.5\%$ $NE\Delta T < 0.5°K$
Scan Rate:	100 km/minute

6.2 Trends in Sensor Parameters

The total number of observations and, consequently, the time required for such observations, varies by an order of magnitude among the top ten priority applications. Three of these require both daytime and nighttime observation, while the remaining seven require daytime observation only. Table 15 shows the proposed number of events, number of targets, total number of observations and time requirements for the ten highest priority applications. The variation in requirements among these applications is such that selection of other applications should not change the picture drastically.

Table 16 illustrates a compilation of the monthly distribution of total number of observations and total time required for these same ten applications. No attempt has been made to distribute these requirements evenly throughout the year, as is evident from the lack of nighttime observation during December and January. Despite a concentration of data requirements in the spring (e.g., March and April), the figures are well below sensor capabilities. It should be explicitly noted that attempts to achieve a more uniform monthly distribution could adversely affect data collection in applications with critical seasonal specifications.

EIFOV requirements in the reflective portion of the spectrum are presented in Figure 6. The values fall in two basic groups, i.e. 100-230 m and 550-700 m, with a single anomaly (1350 m) due to application 4, Monitoring Volcanic Regions. Figure 7 illustrates wavelengths required by the top ten priority applications. Six require thermal IR in the 10.5-12.5 μm band and all have requirements in the 0.4-1.2 wavelength region. A single application calls for a microwave capability at 0.2 to 2 GHz and 10 GHz.

TABLE 15 - Observational Requirements for Top Ten Priority Applications

TOP PRIORITY APPLICATIONS	EVENTS	TARGETS	OBSERVATIONS	TIME minutes	TOTAL TIME minutes	CONSTRAINTS
1	4	2	160	3	480	daytime
2	4	6	1152	4.5	5158	day & night
3	1	2	180	3	2700	day & night
4	1	5	900	3	2700	day & night
5	2	3	312	2.5	780	daytime
6	2	5	960	7	6720	day & night
7	6	1	252	3.6	9073	daytime
8	4	10	520	4	2080	daytime
9	1	4	120	4.5	540	daytime
10	3	2	240	4.5	1080	daytime

TABLE 16 - Monthly Distribution of Required Observations for Top Ten Priority Applications

MONTH	DAY		NIGHT	
	Number Observations	Time	Number Observations	Time
January	102	332		
February	204	828	144	648
March	406	1992	200	1400
April	530	2960	280	1960
May	316	1320	144	648
June	351	1097	75	225
July	325	1285	75	225
August	261	1025	219	873
September	175	615	75	225
October	257	1007	75	225
November	219	1173	219	1173
December	144	380		

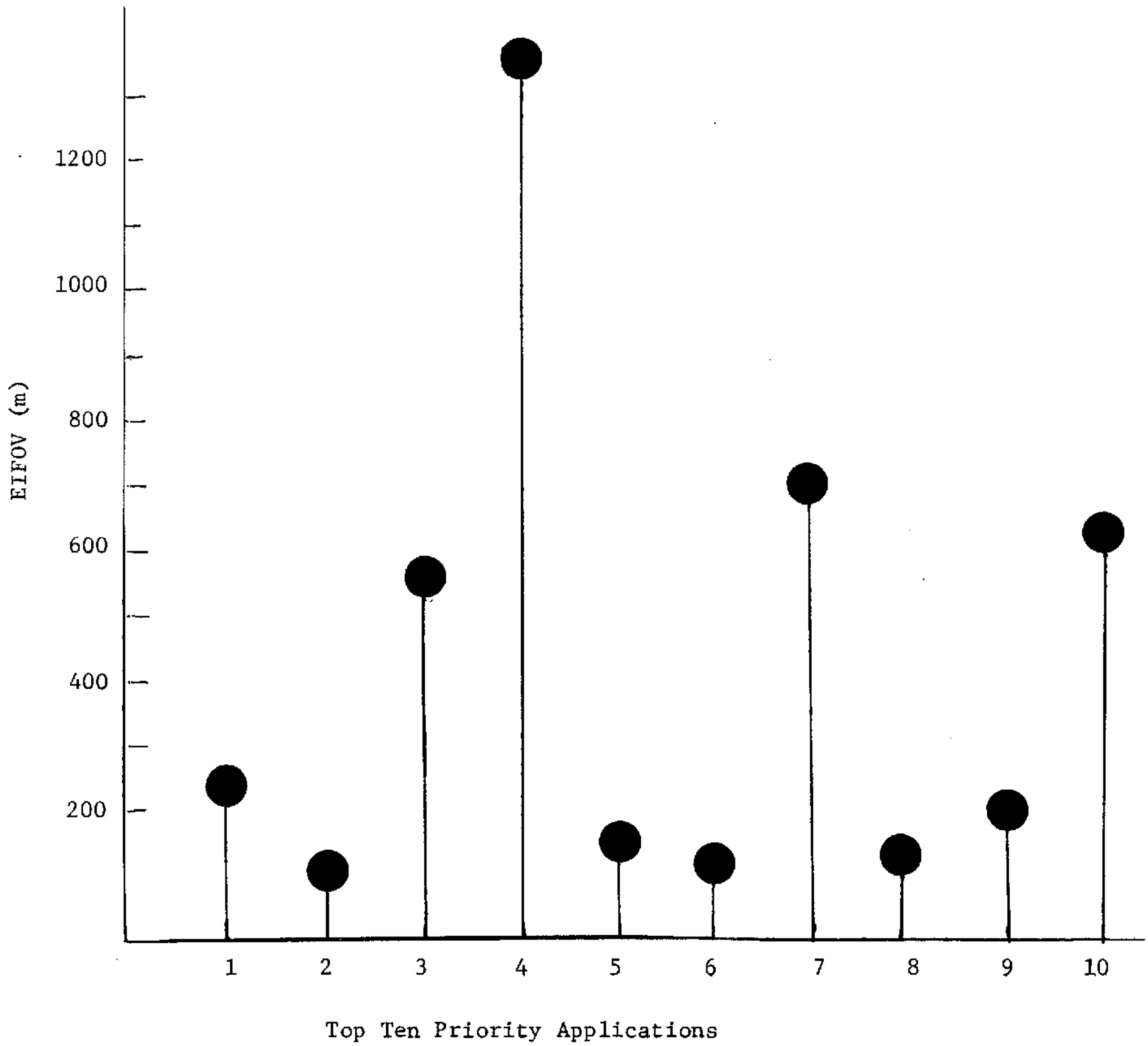

FIGURE 6

EIFOV REQUIREMENTS FOR TOP TEN PRIORITY APPLICATIONS IN REFLECTIVE WAVELENGTH SPECTRAL RANGE

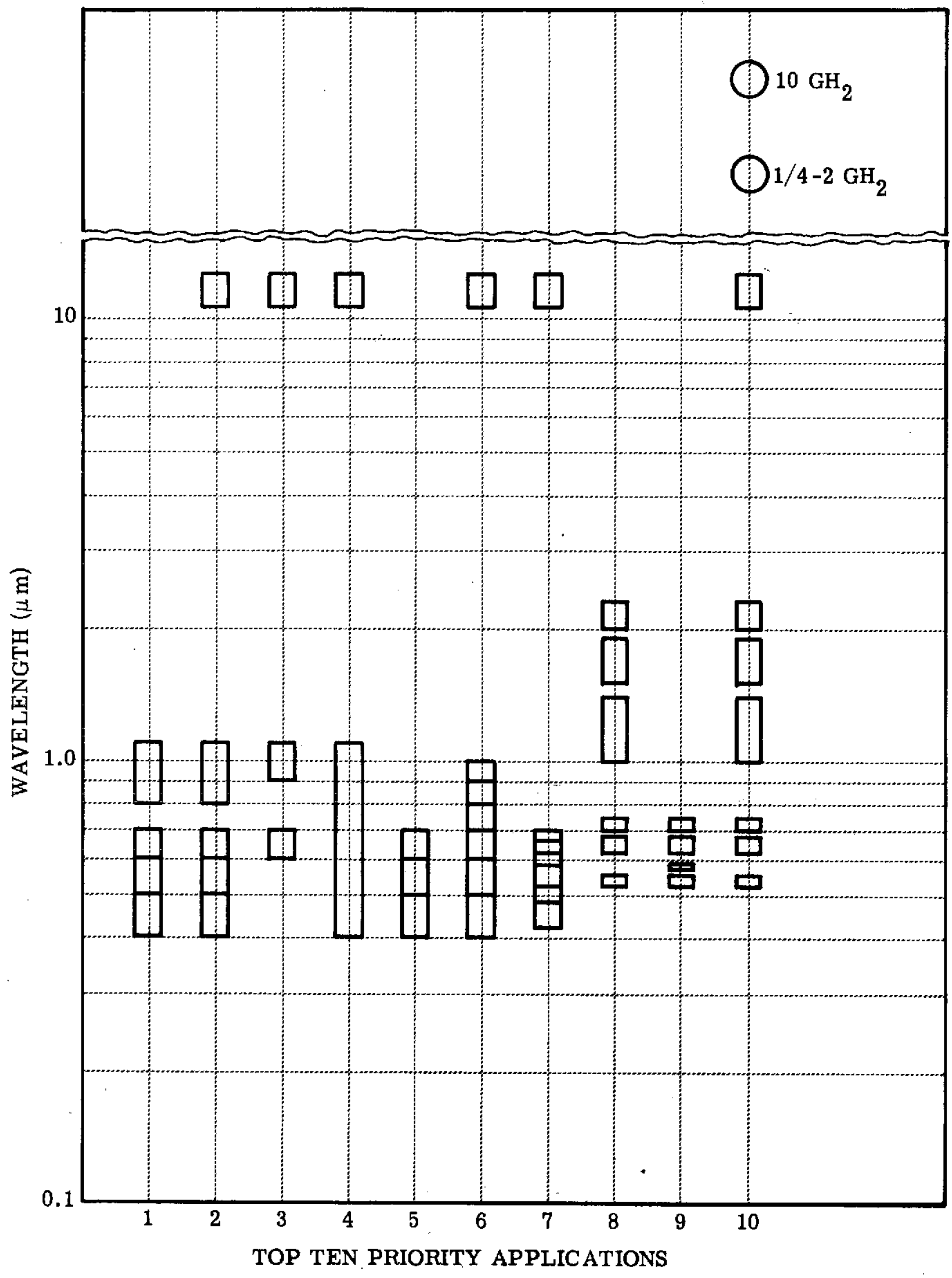

FIGURE 7. WAVELENGTH REQUIREMENTS OF TOP TEN PRIORITY APPLICATIONS

The maximum test site dimension requirements shown in Figure 8 , are seen to range from 50 to 500 km. This figure again indicates two basic groupings, with three applications requiring sites of dimensions near 250 km and five ranging from 100 to 200 km. Here there are two anomalous requirements, 50 km for the plankton study and 500 km for the fish detection application.

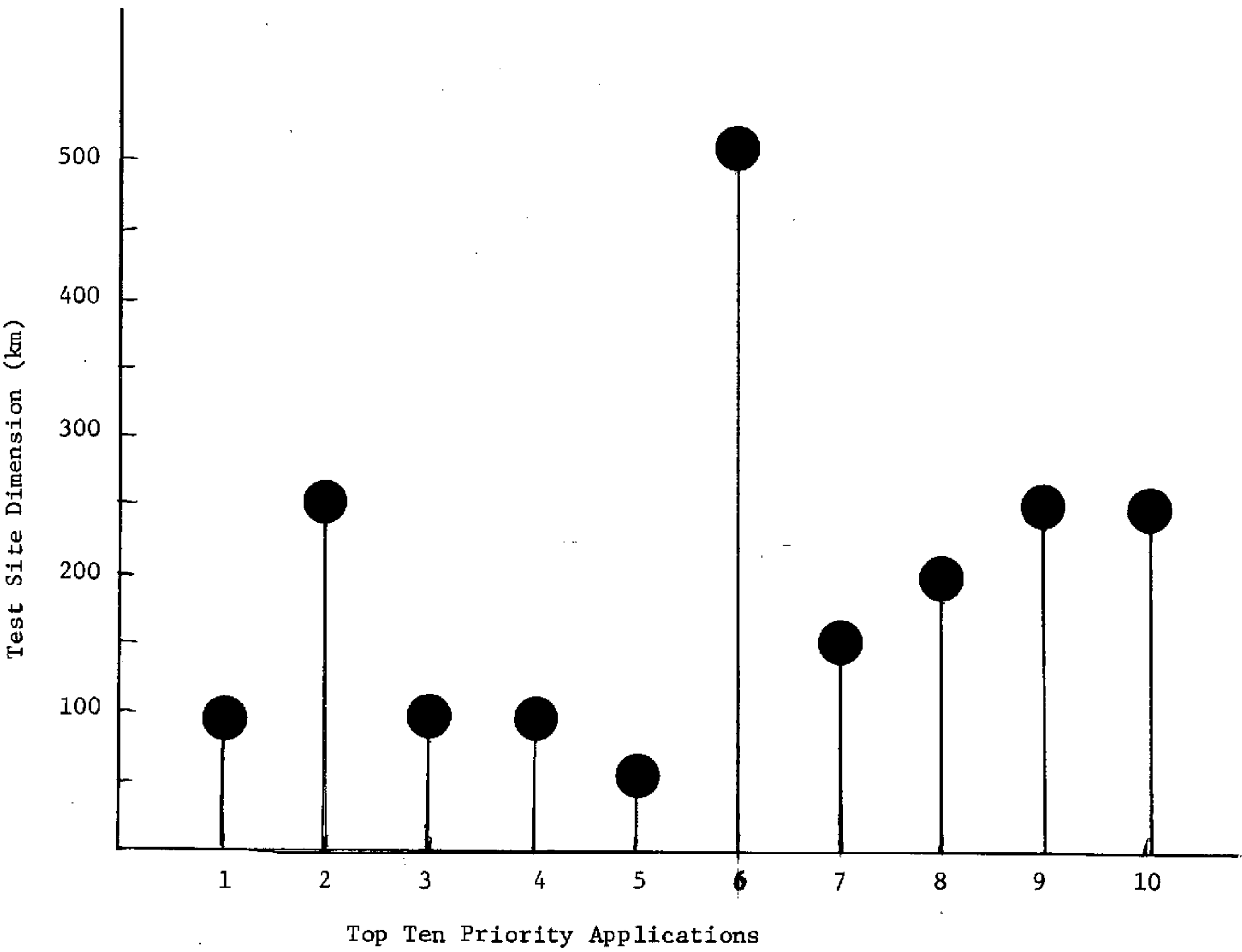

FIGURE 8

MAXIMUM DIMENSION OF TEST SITE REQUIRED
FOR TOP TEN PRIORITY APPLICATIONS

7.0 CONCLUSIONS AND RECOMMENDATIONS

There are a number of earth resource applications which can be satisfied only with a geostationary satellite. These applications all require timely observations of a phenomenon: the phenomenon precedes an unpredictable event, the event itself must be monitored while it is happening or immediately thereafter, or the event must be observed frequently over a precise time interval such as a diurnal cycle. A satellite for making such observation could, of course, make routine observations currently being performed by low orbiting satellites.

Prioritizing the applications and taking the top ten of the thirty-two identified applications, the time required for SEOS to carry out the experiments (application demonstration) is less than 100 hours/month of day and night operation. Thus, it is evident that SEOS can conduct a much larger number of applications simultaneously and the scheduling conflict would occur only when a number of events are of a catastrophic nature and all have immediate, over-riding priority.

The study, by its very nature, is not complete. Many tasks were only lightly treated and in some cases activities were knowingly ignored as being beyond the scope of the study. While this study has identified applications and measurement requirements sufficient to initiate a preliminary sensor system design study, the data in this study need further refinement. Further work should be pursued in the following areas:

1. The SEOS system requirements identified in this study for earth resource applications should be combined with those from the meteorological applications study to develop an integrated set of sensor requirements and establish that the timing demands are compatible.

2. One or two of the application demonstration experiments should be scoped as operational systems to establish and identify any changes in requirements of subsystems in the spaceborne sensor system. In particular, the SEOS for applications demonstration should, if possible, be designed to go operational with minimum impact on the orbiting system.

3. The sensor requirements of NE$\Delta\rho$ should be analyzed with respect to target geographic location and time of observation to generate minimum sensor performance in terms of NER (Noise Equivalent Radiance).

4. The ground data handling requirements for SEOS should be defined and these requirements should go beyond the current ERTS/NDPF data manipulation. Questions should be addressed concerning centralization of such preprocessing activities as

(a) correcting for atmospheric effects
(b) correcting for view angle effects
(c) correcting for sun angle effects
(d) registry of time lapse data
(e) OCC requirements.

5. Evaluate relative importance of each spectral band. If six reflective bands are required, determine the importance of the location of each band as well as the degree of redundancy among the bands.

6. Analyze the resolution requirements to verify that the specified resolution is adequate for machine processing of spectral signatures or image interpretation in accordance with the user's announced requirements.

8.0
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APPENDIX A

Agriculture/Forestry/Range Resources

A1
DETECTION AND ASSESSMENT OF DISEASE AND INSECT DAMAGE TO CULTIVATED CROPS

1. APPLICATION

A period of weather unusually favorable to the development of a damaging agent, the introduction of a new crop genotype, or the mutation of a specific pathogen can result in an explosive increase in normally endemic levels of an insect pest or disease, with consequent widespread damage to cultivated crops. The recent outbreak of southern corn leaf blight is an excellent example. Nationally the 1970 corn crop yield was 15% below the July forecast of that year (USDA, 1971).

In the case of pathogenic damage, the development of a more resistant form of the crop normally remedies the problem over the long term, but to the farmer committed to a particular planting during the pathogen's initial appearance, the market implications of the damage severity and spread are of major importance. Problems associated with insect infestation (e.g., defoliating insects) are less amenable to solution through genotypic manipulation, and the avoidance of serious economic consequences is primarily dependent on early detection and corrective action.

While there are numerous crop-disease-insect relations of considerable economic importance, many (if not most) damaging agents can be expected to result in changes in leaf coloration and morphology, percent cover, and energy-water relations within the affected portion of the crop. Thus, in terms of cultivated crops, the requirements for successfully detecting and assessing damage from either of these primary agents are very similar, and feasibility as well as capability can be investigated as a single application.

Specifically, truck crops along the coastal regions of the central eastern U.S. are subject to several important diseases that presently require extensive preventative spraying treatments. These diseases include late blight of tomatoes and potatoes, downy mildew of cucumbers and virus diseases of celery. Currently, 32 sprayings are made over 10 weeks of the growing season. If infection centers could be located in a timely fashion, i.e., 1 to 2 days after vigor loss is apparent, sprayings could be concentrated on these sites, and the overall number reduced (Blayquez, 1973).

Loss in crop vigor due to such diseases should be correlated with their areal extent to predict the pathogen's effect on overall yield on a regional basis. This would remove much of the market uncertainty and help to stabilize economic conditions.

2. USERS

USDA Statistical Reporting Service
USDA Agricultural Research Service
State Department of Agriculture, Entomology, and Pathology
Extension services
Farmers and intermediate elements of the food preparation and consumption business

3. OBSERVABLE AND CHARACTERISTICS

Most pathogens eventually cause a loss of vigor through interference with the plant's water transport mechanism. When the leaf mesophyll begins to collapse, there is usually an associated change in near infrared (NIR) reflectance and increased foliage temperature due to a reduced capacity for evapotranspiration. There are also often accompanying geometrical changes in foliage orientation (e.g., wilting) with the effect of increasing the visibility of the soil background (Gausman, et al., 1973; Weber and Olson, 1967). Similarly, an increased exposure of the soil background can be expected as one of the earliest indications of a defoliating-insect attack.

Correlation of observable changes in visible reflection and temperature behavior of the foliage with specified levels of damage severity would make possible identification of similarly affected areas.

4. TIME LINE OF EVENTS/OBSERVABLES

Damage Detection: Several truck crops in the central eastern U.S. should be monitored at least twice per week, as soon as foliage signal dominates EIFOV. A sampling scheme concentrating on index control-sites would be most efficient for initial surveillance, followed by supplementary observation of additional areas where disease or insect attach has been detected through field observations.

Damage Assessment: Pathogenic yield-reducing damage often reaches its peak just before a crop begins to mature. This period normally occurs 1 to 1-1/2 months before the crop is harvested. Since normal maturity can be confused with vigor loss, the period when the maximum damage impact can be assessed is both short and critically timed. Considering regional differences in crop maturity, this observation window is considered to be of no more than one week duration.

5. SEOS OBSERVATIONAL REQUIREMENT

To assess the regional severity and spread of the damage, a statistical sampling design is needed. Such a scheme would probably require a sample of 300 to 1000 observation units. Data to accomplish this could be collected in two ways: either by obtaining complete coverage of the central-coastal U.S. and processing only restricted areas, or alternatively, collecting data only over specific sites selected by the sampling plan. Sample (target) size is dependent on the type of crop and the statistical design, but may be expected to be on the order of 20 km x 20 km.

6. SENSOR REQUIREMENTS

$\Delta\lambda$	$\Delta\rho/\Delta T$
.52-.56 μm	1%ρ
.62-.68	
.69-.75	
1.0-1.4	
1.5-1.8	
2.0-2.3	
10.5-12.5	1^{o}C

Thermal band is required.

7. DATA REQUIREMENTS

Data in the following form will prove most useful: 1) thematic maps of disease occurrence and severity; 2) tabulated statistics on damage aggregated by minor civil divisions; 3) access to data by ownership in sampled areas to answer individual inquiries concerning observed vigor loss. For use in disease or insect suppression, detection information must be available within 1 day to allow corrective action.

Necessary ancillary data includes accurate crop identification in the sample sites; ground estimation of causal pathogen or insect infestation and vigor loss in training sets; and models to correlate this decreased vigor with observed reflectivity and temperature changes and the causal mechanism.

8. INTERIM ACTIVITIES

Basic biophysical studies are needed to better define the nature of stress reaction in crops and more positively quantify the relationship of foliage reflectance to change in vigor. This could easily be a five year program utilizing ground, aircraft and ERTS data to systematically arrive at the most effective sensor specifications and processing philosophy for different types of crops.

9. IMPORTANCE/JUSTIFICATION

Crop losses of up to 15-20% could be forecast far enough ahead to stabilize the dependent market and agricultural processing industry.

10. SEOS UNIQUENESS

SEOS capability is not unique, but due to the short period of most effective damage inventory, it is well suited to this application.

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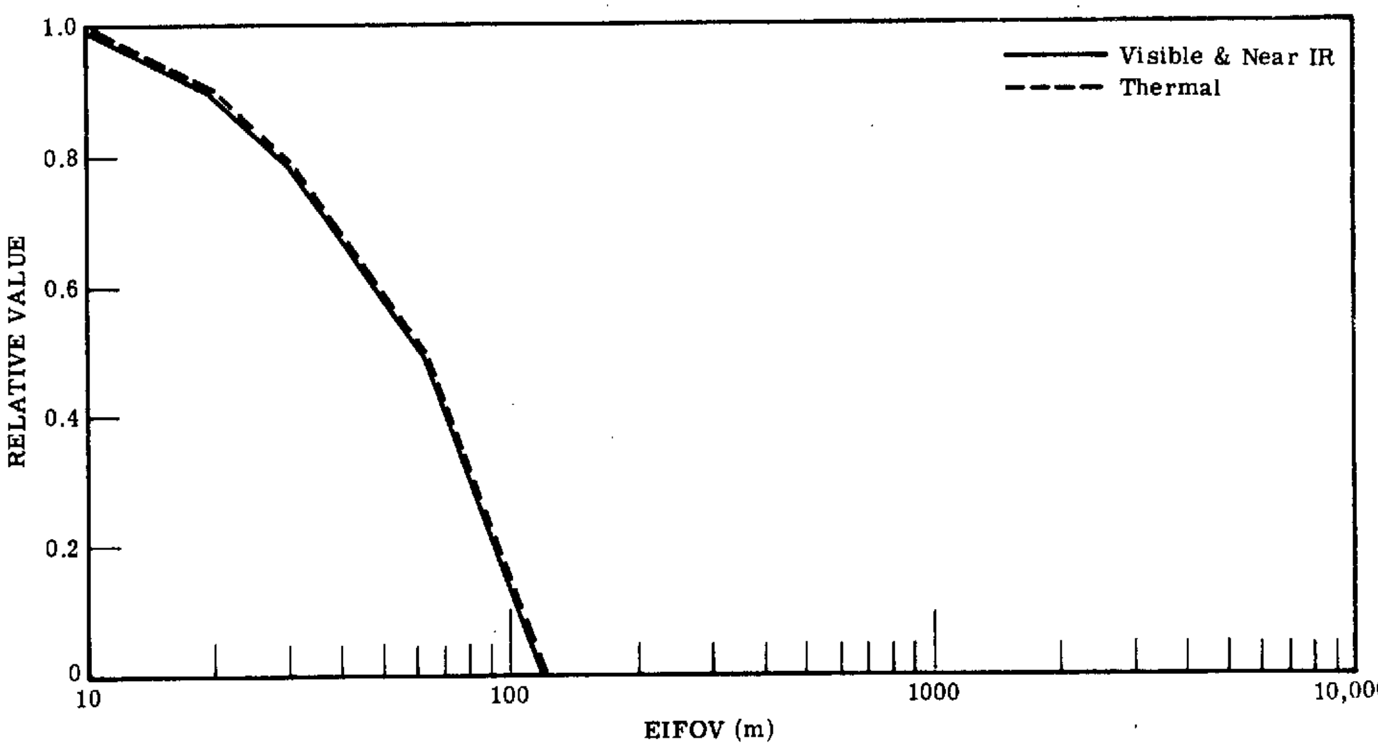
ERIM

SEOS APPLICATION SUMMARY

DETECTION AND ASSESSMENT OF DISEASE AND INSECT DAMAGE TO CULTIVATED CROPS	APPLICATION	
USDA Statistical Reporting Service USDA Agricultural Research Service State Department of Agricultur, Entomology, and Pathology Extension services Farmers and intermediate elements of the food preparation and consumption business	USER	
a) Change in NIR reflectance of foliage due to leaf mesophyll collapse; increased foliage temperature due to blockage of water transport mechanism and resultant decrease in evapotanspiration ability; increased soil contribution to scene reflectance due to damage in leaf geometry, i.e., wilting. b) Pixel spectra; investigate changes in foliage NIR reflectances, temperature, and increases in soil reflectance.	OBSERVABLE AND CHARACTERISTICS	
Mid to late summer	Season	TIME LINE OF EVENT
8 weeks Observation window: <1 week visible, 4 hours thermal	Duration	TIME LINE OF EVENT
5	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
4	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
Detection 2 per week	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Coastal region of central eastern U.S.	Geographic Location	SEOS OBSERVATION REQUIREMENTS
20 x 20 km.	Dimensions (m., Km.)	
10 m. nominal, see attached graph	EIFOV (m.)	SENSOR REQUIREMENTS
MSS: visible .52-.56 μm, .62-.68, .69-.75; NIR 1-1.4, 1.5-1.8, 2-2.3; Thermal 10.5-12.5 Thermal band is required.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
1%ρ 1°K	Δρ, ΔT (%, °C)	SENSOR REQUIREMENTS
1. Thematic maps of reduced vigor. 2. Statistics for minor civil divisions. 3. Access to data by ownership to answer individual enquiries & for distribution to local agriculture agent.	Format	DATA REQUIREMENTS
1 day	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Crop ID/location and on the ground confirmation of pathogenic agent and test site, estimate of productivity loss or correlation with reduced reflectance.	Ancillary Data	DATA REQUIREMENTS
Basic biophysical studies to determine relationship of ρ change to vigor/and or damage vector (A,F,A/C, S/C)	Study	INTERIM ACTIVITIES
60 mm	Level	INTERIM ACTIVITIES
1973-1978	Time Frame	INTERIM ACTIVITIES
Ground, aircraft, ERTS	Platform	INTERIM ACTIVITIES
1-2 billion, High	IMPORTANCE/ JUSTIFICATION	
Not unique, but can make an important contribution by obtaining data in a timely fashion.	SEOS UNIQUENESS	



APPLICATION: Detection and Assessment of Disease and Insect Damage to Cultivated Crops

A2

DETERMINATION OF OPTIMUM CROP PLANTING DATES

1. APPLICATION

Natural vegetation communities serve as a good index for timing the planting of many important agricultural crops. For example, bud burst of white oak is a good indicator of when to plant corn (Platt, 1953). Another important indicator is soil temperature, which must reach a point where seed viability will not be adversely affected. Soil moisture must also be considered where heavy machinery is to be used (Buckman and Brady, 1967).

Regional knowledge of these conditions on a local basis, when coupled with accurate weather forecasting, can help the individual farmer make a more effective decision of when to plant. By planting earlier, the farmer can obtain a greater yield by making better use of available water supplies earlier in the season.

To demonstrate the potential contribution of a geosynchronous remote sensing satellite to this application, the optimum planting date of corn in the central U. S. could be determined for one growing season.

2. USERS

USDA Statistical Reporting Service
Farmer's cooperatives
Seed, farm machinery and fertilizer industries

3. OBSERVABLE AND CHARACTERISTICS

The changing visible and near infrared reflectance patterns of key vegetation communities corresponding to the foliage flushing are major observables.

Thermal data have been shown to be useful for assessing soil moisture (Meyers and Heilman, 1968; Wiegand, 1966). First, such data provide a direct means of measuring the soil temperature and secondly, ratios of thermal data have shown considerable promise for delineating soil moisture regimes (Wagner et al., 1973).

Radar in the 1/4-2 gigahertz frequencies has also proven useful in determining soil moisture and could penetrate the cloud cover often present in the spring.

4. TIME LINE OF EVENTS/OBSERVABLES

The observation period is in the spring, over a one month period, as the "green wave" progresses from south to north.

5. SEOS OBSERVATIONAL REQUIREMENT

Index sites in 10 major corn producing states in the south and midwest would be optimum target sites. These should be located systematically to account for latitude and longitudinal variations in climate.

Key natural vegetation communities would be examined during the day and soil temperature and moisture at night. As the optimum planting date was determined in an area monitoring of that site would be dropped.

Target areas should be 40 x 40 km. Index fields and vegetation communities should be at least 80 acres.

6. SENSOR REQUIREMENTS

MSS	$\Delta\rho$	Radar
.52-.56 μm	1%	1/4-2 gigahertz and 10 gigahertz
.62-.68	1%	
.69-.75	1%	
1-1.4	1%	
1.5-1.8	1%	
2-2.3	1%	
8.3-9.3	1°K	
10.5-12.5	1°K	

Thermal band is required.

7. DATA REQUIREMENTS

Data are needed to provide farmers with a plant or don't plant decision on a daily basis. This should take the form of thematic maps of natural vegetation development and soil temperature and moisture (by type).

Ancillary data on soil types and weather forecasts are necessary to complete the task.

8. INTERIM ACTIVITIES

Studies must be made to determine the key regional-index natural vegetation communities, and their spring reflectance patterns. Field, aircraft, and ERTS studies are necessary at least one year in advance of operationally determining the planting date.

9. IMPORTANCE/JUSTIFICATION

Farmers will base their planting decision on the best available information. Information which enables them to plant at the optimum time (i.e., as soon as possible) will ensure that they will have the maximum opportunity to increase yield through full utilization of the early growing season soil moisture. Yield increases would be very significant, providing increased crops amounting to perhaps $2 to 4 million per year.

10. SEOS UNIQUENESS

The ability of SEOS to do this job is unique because of the requirement for diurnal observation.

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Platt, R. 1953. A pocket guide to trees. Simon and Schuster, Inc. New York. 256 p.

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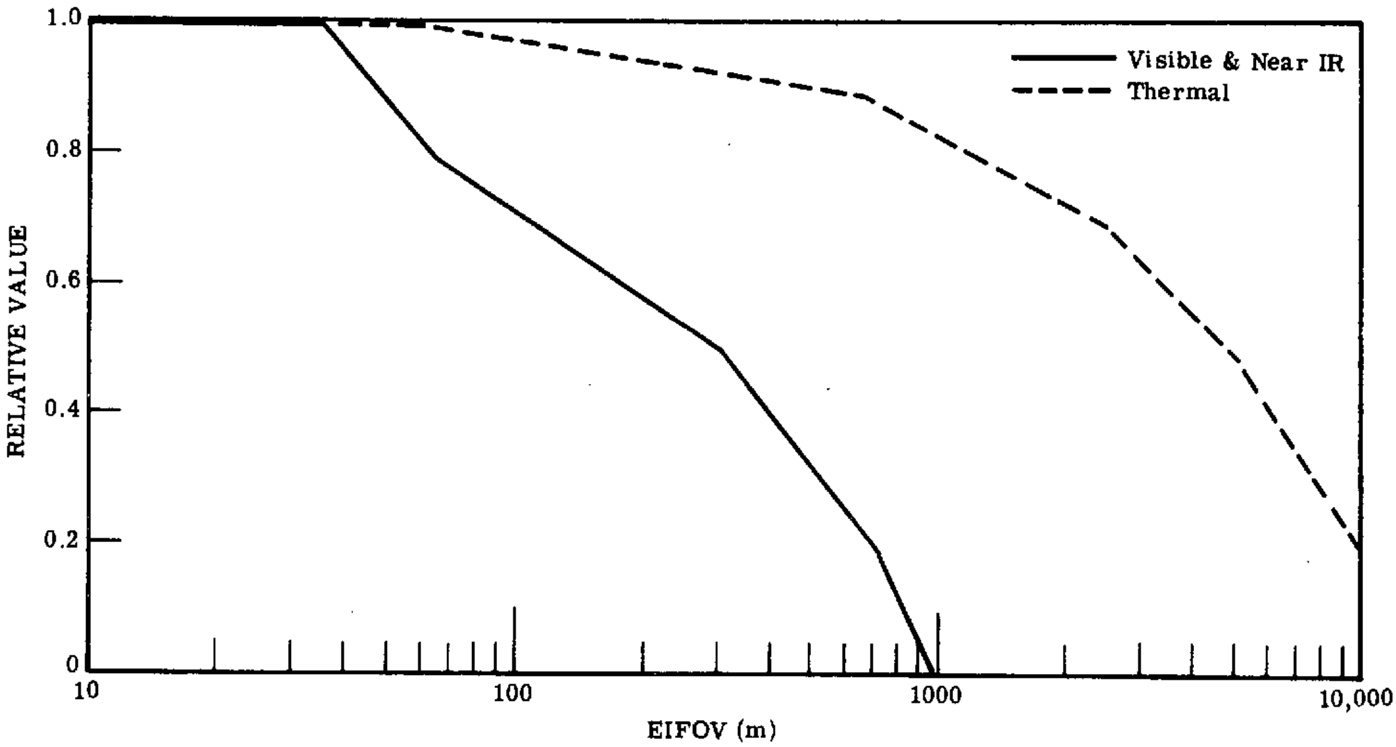
SEOS APPLICATION SUMMARY

ERIM

DETERMINATION OF OPTIMUM CROP PLANTING DATES	APPLICATION	
USDA Statistical Reporting Service Farmer's cooperatives Seed, farm machinery and fertilizer industries	USER	
a) Phenology of natural vegetation index communities and soil temperature and moisture characteristics. b) Pixel spectra on a daily basis.	OBSERVABLE AND CHARACTERISTICS	
Spring	Season	TIME LINE OF EVENT
1 month; Observation window: 2 hours	Duration	TIME LINE OF EVENT
(1)	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
2/state, 10 states in corn belt (20)	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
Daily for up to 30 days	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
1 site in NW of state 1 site in SE of state	Geographic Location	SEOS OBSERVATION REQUIREMENTS
40 x 40 m.	Dimensions (m., Km.)	
Visible and NIR nominally 3 m. Thermal nominally 500 m. See attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
MSS .52-.56μm, .62-.68, .69-.75, 1.0-1.4, 1.5-1.8, 2.0-2.6; 8.3-9.3 μm, 10.5-12.5μm; RADAR 1/4-2 gigahertz; Thermal band is required.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
1% 1°K S/N<1	$\Delta\rho$, ΔT (%, °C)	SENSOR REQUIREMENTS
Thematic maps of isovegetation development and soil temperature and moisture conditions together with computer compatible tapes	Format	DATA REQUIREMENTS
Data requirements: 12 hours	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Soil types, vegetation cover types, 1-3 day weather forecasts.	Ancillary Data	DATA REQUIREMENTS
Determine key regional nat. vegetation index communities (A,F, A/C)	Study	INTERIM ACTIVITIES
12mm	Level	INTERIM ACTIVITIES
1975-1976	Time Frame	INTERIM ACTIVITIES
Ground study and feasibility of their aerial detection.	Platform	INTERIM ACTIVITIES
Moderate	IMPORTANCE/ JUSTIFICATION	
Unique, because of daily observation requirement over extended period.	SEOS UNIQUENESS	



APPLICATION: Determination of Optimum Crop Planting Dates

A3

PHENOLOGICAL CLASSIFICATION OF AGRICULTURAL CROP TYPES

1. APPLICATION

The use of the time dimension as a discriminating variable to aid in crop identification is well known. In effect, crop-specific change patterns of filiar reflectance and/or morphology, associated with increasing maturity, become the means of discriminating crop types.

For this technique to be successful, multidate observation is required. Problems arise, however, as optimal data collection windows are often of short duration, and do not necessarily occur systematically throughout the growing season. Cloud cover constraints on data collection in this aspect is a serious problem. Weather conditions in mid to late summer over the central and western parts of the U. S. are often such that it is quite probable that entirely cloud-free days will not occur with sufficient regularity. Yet, partially cloudy days, where the mornings are relatively cloud free may reduce the seriousness of this problem if precise observation time is sufficiently flexible.

In addition, further support for utilizing a geosynchronous satellite for this application comes from current work which emphasizes how timely data collection, based on current growing season conditions, can eliminate much of the redundant sampling inherent in this approach when used on a routine and systematic observation basis.

Using the agricultural concept of degree/days as an index to maturity, if one knows when growth initiates, i.e., when a critical threshold air temperature is reached locally, and has kept track of degree/days accumulating subsequently, by using weather forecasts judiciously, he can predict when major phenological events will occur for specific crops in the current growing season (Anderson and Rhode, 1973).

With a geosynchronous remote sensing satellite using this approach, crops could be observed locally at the height of any particular phenological stage, and cloud cover constraints could be minimized. For many crops only

2 or 3 critical observations would be necessary for discrimination. By selectively observing at the appropriate time, redundant sampling and processing costs are reduced.

In summary, a geosynchronous remote sensing satellite will make phenological identification of crops cheaper, more accurate and less subject to weather constraints.

2. USERS

USDA-SRS, ASCS

Individual farmers and cooperatives

State Departments of Agriculture

Extension services

Intermediate elements of the food production and consumption business

3. OBSERVABLE AND CHARACTERISTICS

The changing visible and near infrared reflectance patterns of various agricultural crops are major observables.

These data must be processed on a temporal basis to yield a new variable representing change over time (Steiner, 1969).

4. TIME LINE OF EVENTS/OBSERVABLE

Observation period extends over the entire growing season. However, narrow observation windows exist within this period for each individual crop. Usually these windows represent a bare soil-newly planted phase, an observation at the height of the "green" phase during a period of maximum growth, and an observation during crop senescence.

5. SEOS OBSERVATIONAL REQUIREMENTS

As a demonstration, the acreage of corn, soybeans and hay would be determined for specific index sites in four states: Iowa, Nebraska, Illinois, and Indiana.

Observation for each crop should be made locally during the optimum three day period for discrimination of a particular phase of crop development, based on current and predicted weather conditions. Target areas should be 200 x 200 km.

6. SENSOR REQUIREMENTS

	MSS	$\Delta\rho$
Visible	.52-.56 μm	1%
	.62-.68	"
	.69-.75	"
NIR	1-1.4	"
	1.5-1.8	"
	2-2.3	"

7. DATA REQUIREMENTS

Data are needed in the form of field crop type maps and tabulated statistics of acreage in specific crops.

Ancillary data include local initiation of growth (threshold air temperature occurrence) by crop, subsequent accumulation of degree days, and local weather forecasts. Plot maps of land ownership and location of non-agricultural land on topographic based maps is also desirable.

8. INTERIM ACTIVITIES

Studies must be made to determine the size of the observation window of initial phenological events of major crops, as well as the most discriminating set of events for each crop. Field, aircraft and ERTS studies are necessary in a two year program in advance of this demonstration.

9. IMPORTANCE/JUSTIFICATION

Crop acreage estimates are an essential part of agricultural programs throughout the world because they provide basic data for research, program planning and administration. They help farmers plan plantings, serve as direct measures of land utilization and are prime indicators of the future demand for farm supplies and labor. The importance of this application is extremely high.

10. SEOS UNIQUENESS

The ability of SEOS to do this job is not unique, but it may be the most optimally suited remote sensor platform for this application due to critically timed observation windows over an extended period.

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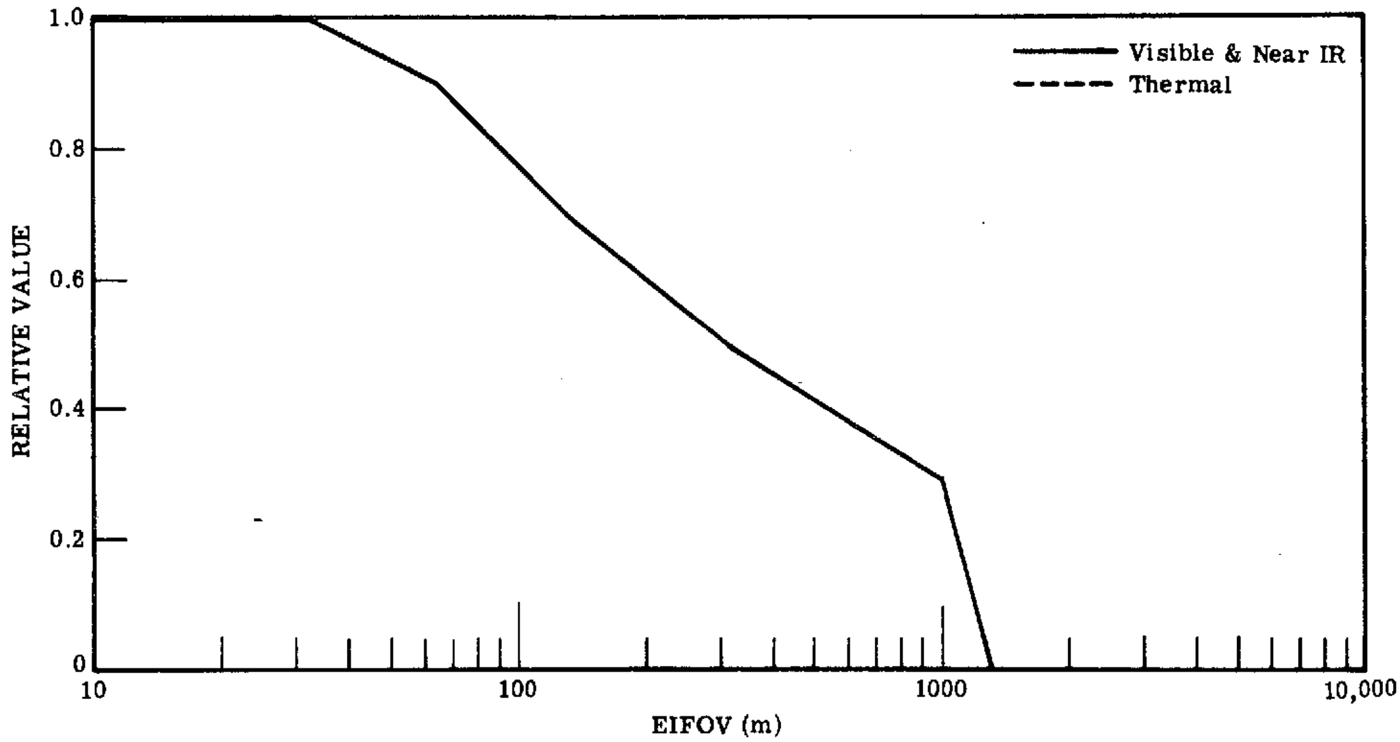
Steiner, D. 1969. Using the time dimension for automated crop surveys from space. Amer. Soc. Photogramm., 35th Annual Meeting, Tech, Papers, pp. 286-300.

SEOS APPLICATION SUMMARY

PHENOLOGICAL CLASSIFICATION OF AGRICULTURAL CROP TYPES	APPLICATION	
USDA Statistical Reporting Service Agriculture Stabilization and Conservation Service Individual farmers and cooperatives State Departments of Agriculture Extension Services All intermediate elements of the food production and consumption business	USER	
a) Changing patterns of visible and NIR reflectance with crop development. b) pixel spectra at various stages of crop development	OBSERVABLE AND CHARACTERISTICS	
Spring-Fall	Season	TIME LINE OF EVENT
6 mo. Observation window: 3 days	Duration	TIME LINE OF EVENT
3/crop (9)	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
3/state (12)	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
1	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Corn belt states, Iowa, Nebraska, Illinois, and Indiana.	Geographic Location	SEOS OBSERVATION REQUIREMENTS
200 x 200 km	Dimensions (m., Km.)	
30 m. nominal, see attached graph	EIFOV (m.)	SENSOR REQUIREMENTS
MSS Visible .52-.56 μm, .62-.68, .68-.75; NIR 1 - 1.4, 1.5 - 1.8, 2 - 2.3	Wavelength Interval (μm)	SENSOR REQUIREMENTS
170	Δρ, ΔT (%, °C)	SENSOR REQUIREMENTS
1) Cover type maps of Ag. fields. 2) Tabulated statistics of acerage in each crop.	Format	DATA REQUIREMENTS
2 weeks	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Topographic base maps and plot maps. Local weather data and forest accumulated degree days. Knowledge of initiation of crop growth.	Ancillary Data	DATA REQUIREMENTS
Identify most discriminant combination of phenological events for each crop. Determine size of observation window for major phenological events. (A,F, A/C, S/C)	Study	INTERIM ACTIVITIES
24 min.	Level	INTERIM ACTIVITIES
1976-1977	Time Frame	INTERIM ACTIVITIES
field, aircraft & ERTS	Platform	INTERIM ACTIVITIES
Extremely high.	IMPORTANCE/ JUSTIFICATION	
Not unique, but optimally suited platform.	SEOS UNIQUENESS	



APPLICATION: Phenological Classification of Agricultural Crop Types

A4

DETECTION AND ASSESSMENT OF INSECT DAMAGE TO FOREST SPECIES

1. APPLICATION

The effective management and regulation of forest productivity requires accurate and timely information on tree vigor, for this is a direct measure of growth (i.e., productivity). Although recent data indicate that, in gross terms, U. S. tree growth exceeds the total drain due to loss and harvest (U. S. Forest Service, 1958), much of the growth accrues on low-value undesirable species and on trees of poor form, while cutting is concentrated on the more valuable, high quality trees. This, coupled with losses to disease or insect attack, can produce a cumulative drain on the most valuable commercial species.

Insect infestations cause severe damage and decreased growth in valuable commercial species, ranging from steadily increasing effects such as the budworm defoliation of spruce in Maine during the early 1950's (Waters, et al., 1958), to the epidemic attack of bark beetle on the pines of Central America in 1963. During this latter epidemic some 60% of the merchantable timber was killed in an 18-month period (Heller, 1971).

In other cases, damage due to insect attack does not result in immediate or outright destruction of valuable timber, and early detection can guide successful salvage operations to harvest affected trees which simultaneously serves to stem the spread of the damaging agent. Further, these agents can reduce growth rate even when merchantable material is not directly attacked and the agent does not kill the tree (Graham and Knight, 1965). Here again, the key to effective management is early detection of reduced vigor and prompt corrective action.

Since vegetation stress symptoms are often similar regardless of the damaging agent (Heller, 1971), the feasibility of, and capability for, successful detection and assessment of many types of insect damage could be accomplished by a single, meaningful investigation of one major pest. The gypsy moth is a destructive forest pest particularly injurious to broad-leaved trees in the New England states, although pines are by no means immune (Graham and Knight, 1965).

Relationships between expected defoliation and subsequent condition and mortality rate among the defoliated trees are almost always important factors in deciding if, when, and where to take corrective action. Unfortunately, information on the after-defoliation condition and mortality rate of trees over large areas and on different sites is lacking. Information is also needed on reflushing rates of defoliated trees and effects of secondary and tertiary defoliation within and during subsequent growing seasons (Campbell and Valentine, 1972). Relating this knowledge to site index, stand composition and maturity will effectively improve planning and evaluation of suppression efforts.

2. USERS

U. S. Forest Service
State Departments of Natural Resources
Northeast Forest Experiment Station entomologists
State and university entomologists
City foresters
Private woodlot and residence owners
Veneer industry

3. OBSERVABLE AND CHARACTERISTICS

Key observables are partial or complete defoliation with increased exposure of soil and litter background due to gypsy moth attack on numerous eastern deciduous trees.

To provide the necessary information on reflushing or mortality, sites of known gypsy moth defoliation should be observed several times during the growing season.

These sequential looks should be used to stratify defoliating patterns on the site through temporal comparison of NIR reflectance patterns. Field crews would then collect data on species of interest, and associated site conditions.

4. TIME LINE OF EVENT/OBSERVABLE

Gypsy moth:

Observation should be made at one month intervals, beginning at the end of June through September.

5. SEOS OBSERVATIONAL REQUIREMENT

Gypsy moth:

Ten key index sites, defined by forest entomologists based on past defoliation patterns, should be analyzed for four different dates.

The northeastern U. S. provides the best geographic region for a demonstration.

An observation format of 200 x 200 km would permit an important synoptic view of regional conditions for either demonstration.

6. SENSOR REQUIREMENTS

MSS	%ρ
.52-.56 μm	1%
.62-.68	1%
.69-.75	1%
1.0 -1.4	1%
1.5 -1.9	1%
2 - 2.3	1%

7. DATA REQUIREMENTS

Gypsy moth:

Data relating reflectance patterns to degree of defoliation are required for each observation. Patterns of change between observations are of major interest. This data should be in overlay form to permit field crews to locate plots for ground surveys of reflushing characteristics.

Necessary ancillary information includes coordinates of known gypsy moth damage to serve as index sites, topographic maps for registration with vegetation reflectance change data, and forest cover type maps.

8. INTERIM ACTIVITIES

Gypsy moth:

Studies to determine the levels of defoliation detectable from satellite altitude at varying resolutions are needed. Additionally, the effects of litter and other background on the stability of defoliation-reflectance change relationships requires investigation.

9. IMPORTANCE/JUSTIFICATION

The value is high for aesthetic reasons and in terms of annual timber and veneer losses. Average expenditures for control of the gypsy moth alone, by State and Federal agencies between 1938 and 1958, were $1,893,000/yr. The growth impact for 1952 was 16.3 million cubic feet of growing stock lost (USDA-Forest Service Report No. 14). Root rot results in 170 million board feet lost per year.

10. SEOS UNIQUENESS

SEOS capability is unique, but it is well suited to insuring the necessary coverage needed to identify defoliated areas when optimum background contrast conditions exist.

LITERATURE CITED

Campbell, R. W. and H. T. Valentine, 1972. Tree condition and mortality following defoliation by the gypsy moth. USDA Forest Ser. Res. Paper NE 236, 331 pp.

Graham, S. A. and F. B. Knight. 1965. Principles of forest entomology. McGraw-Hill, New York 417 pp.

Heller, R. C. 1971. Detection and characterization of stress symptoms in forest vegetation. In Proc. Int. Workshop on Earth Res. Survey Systems. NASA 2: 109-150.

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Waters, W. E., R. C. Heller, and J. L. Bean. 1958. Aerial appraisal of damage by the spruce budworm. J. Forestry 56: 269-276.

Wear, J. F. 1967. The development of spectro-signature indicators of root disease on large forest areas. Am. Prog. Rept. Forestry Remote Sensing Laboratory for Natural Resource Program, NASA, by the Pac. So. West For. and Range Exp. Sta. 22 pp.

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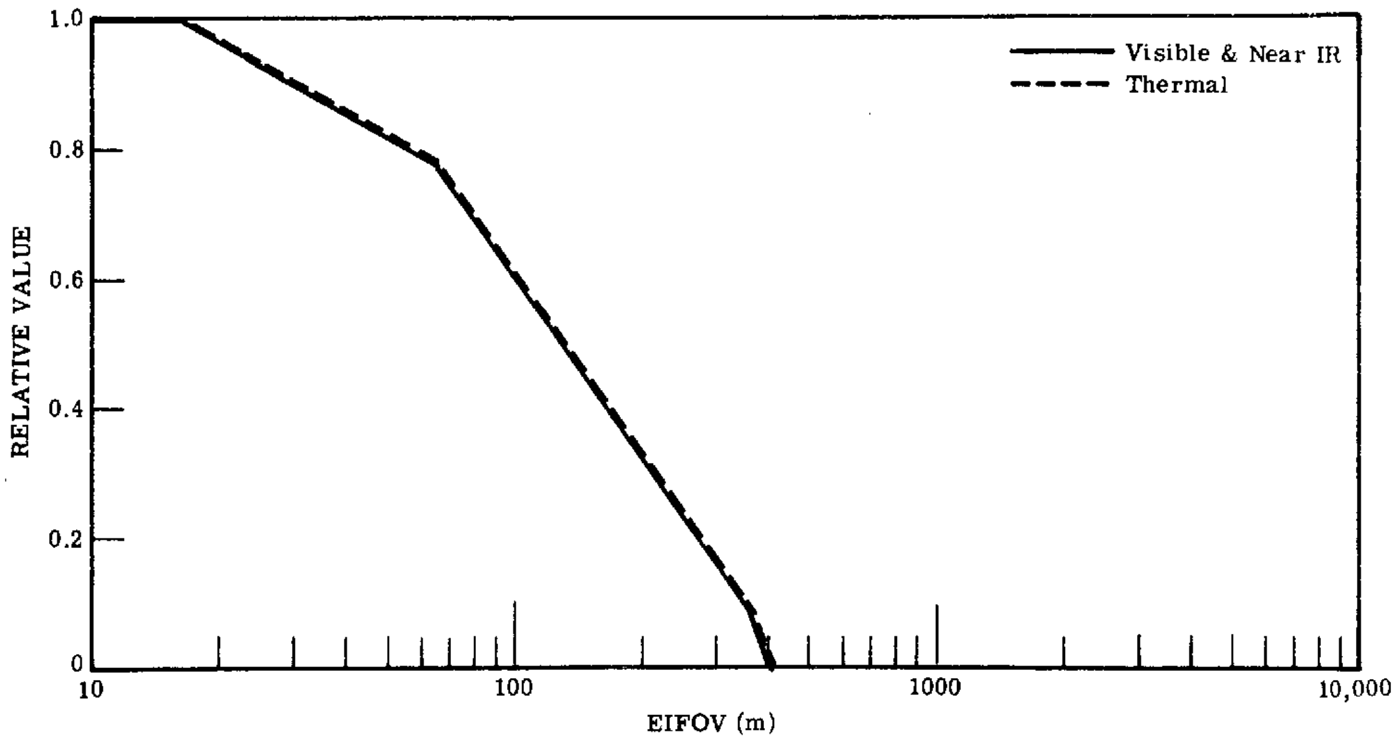
SEOS APPLICATION SUMMARY

ERIM

DETECTION AND ASSESSMENT OF DISEASE AND INSECT DAMAGE TO FOREST SPECIES.	APPLICATION	
U.S. Forest Service State Departments of Natural Resources Forest Experiment Stations City Foresters; Forestry Products Industry Home and woodlot owners Veneer Industry	USER	
a) Partial or complete defoliation. b) Pixel spectra and their temporal change. c) Thermal variations, diurnally and seasonally.	OBSERVABLE AND CHARACTERISTICS	
Spring-summer	Season	TIME LINE OF EVENT
4 months; 1 three-day interval each month; observation window: visible.	Duration	TIME LINE OF EVENT
4 <1 wk; thermal 4 hrs.	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
10 Northeastern U.S.	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
1 Northeastern U.S.	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Northeastern U.S. Mass. Conn. Vermont, New York Northwestern U.S. Washington, Oregon	Geographic Location	SEOS OBSERVATION REQUIREMENTS
200 x 200 km	Dimensions (m., Km.)	
15 m. nominally; see attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
VIS: .52-.56 μm, .62-.68, .69-.75 NIR: 1-1.4, 1.5-1.8, 2-2.3 Thermal band is required.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
1%	Δρ, ΔT (%, °C)	SENSOR REQUIREMENTS
1) thematic maps of isodefoliation 2) overlays to show occurence of reflushing 3) tabulated statistics on defoliation change 4) overlays of isothermal contours.	Format	DATA REQUIREMENTS
1 mo.	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Location of known defoliation sites Forest cover type maps.	Ancillary Data	DATA REQUIREMENTS
Studies to assess the degree to which we can reliably determine defoliation level from satellite altitudes (A,F, A/C, S/C)	Study	INTERIM ACTIVITIES
1 mm	Level	INTERIM ACTIVITIES
1975-1976	Time Frame	INTERIM ACTIVITIES
Ground, aircraft, ERTS	Platform	INTERIM ACTIVITIES
Moderate to high.	IMPORTANCE/ JUSTIFICATION	
Unique, due to requirement for diurnal observations and critically narrow observation windows.	SEOS UNIQUENESS	



APPLICATION: Detection and Assessment of Disease and Insect Damage to Forest Species

A5

FOREST INVENTORY AND VALUATION FOR MULTIPLE-USE MANAGEMENT

1. APPLICATION

Forest resource surveys conducted by the U. S. Forest Service gather data by region, with gross figures by states, but do little to determine the exact location of the resources (U. S. Forest Service, 1958). Many states pay increased costs of more intensive surveys within their borders. Michigan paid an additional $286,500 to obtain enough data for a county summary of its forest resources (Willow Run Laboratories, 1966; U.S. Forest Service, 1967). The production of "stand maps" in the vicinity of the Forest Service's permanent sample points, which are used to provide the above figures, would greatly aid in determining the nature of the ecological changes on a site between inventories. It is possible that a satellite system would do this with the same accuracy as present ground surveys and in a less costly and more timely fashion.

When a reliable map of forest distribution is available for an area to be inventoried, improved statistical design is possible. This will permit reduction of the amount of ground sampling required to achieve a given degree of accuracy when inventorying large areas (Husch et. al., 1972).

Identification of forest cover types from multipass satellite data is at best, difficult. With SEOS, observations can be limited to coincide with dates of important phenological phenomena. Variables of interest, in this regard, are:

1. The data of leaf flushing
2. Description of immature foliage
3. Time of fall coloring
4. Description of fall colors
5. The time of leaf fall (Sayn-Wittgenstein, 1961)

Aspen, for instance, can be characterized as: (1) one of the first species to leaf out in the spring, its foliage being well developed as early as late April; (2) having a light yellow color in the fall; and, (3) leaves persistant until late October. This combination would allow one to classify aspen which is perhaps the most important forest species in the Lake States at the present time. It is not only the basis for an extensive pulp wood industry, but forms the major food source for many of the most important game species for a large part of the year, particularly white-tailed deer and ruffed grouse.

The Michigan DNR has stated "[wildlife habitat] management will be concerned with the preservation of the aspen type ..." (Byelich et. al., 1972). Furthermore, they intend to "maintain a desirable proportion of aspen type; not less than 35% of upland area." In fiscal year 1971-1972, $616,000 was allotted by the State of Michigan along for application of a large-scale program of deer habitat management.

2. USERS

U. S. Forest Service
State Departments of Natural Resources
National Park Service
Forest products industry
Natural resource departments of foreign governments
Outdoor recreation industry
Food and agriculture organization

3. OBSERVABLE AND CHARACTERISTICS

Many other important deciduous forest species besides aspen display unique phenological foliage reflectance patterns. In the temperate zones, this pattern manifests itself as a color change each year prior to leaf fall. In this period there are several days during which individual species exhibit characteristic differences in color. Thus, the radiation observables of importance are foliage reflection patterns during their critical season.

At this season an extensive forest inventory can be greatly simplified, solely on the basis of observed hue. The distinction between deciduous and evergreens (excepting tamarack) is simplified by the fact that evergreens remain dark green. Lowlands species, such as the elms, birches, ironwood, silver maple and tamarack turn yellow or light brown. Red maple turns a brilliant red. The upland beech and oaks have their own characteristic russet or reddish-brown color.

Furthermore, there is a distinct sequence to this change. Lowland species in swamps or depressions usually change colors first because of frosts. Later, during the winter, confierous forest cover can be simply separated from deciduous species by comparing changes in forest cover extent and location. In winter, only confiers will possess the characteristic reflectance of green foliage.

4. TIME LINE OF EVENTS/OBSERVABLE

Fall changes of color occur over a 1 to 2 month period at the end of each growing season.

5. SEOS OBSERVATIONAL REQUIREMENT

Repreated looks will be necessary to cover the full range of and species' color change. The actual number of observations is dependent on the range of species and time it takes for the annual color change sequence. A suitable target would be one corresponding to some civil divisions, e.g., group of countries, state, province or small country. A target size of 250 x 250 km would be suitable for an experimental demonstration.

6. SENSOR REQUIREMENTS

λ (μm)	$\Delta\rho$%
.52-.56	1
.57-.59	1
.59-.62	1
.62-.68	1
.69-.75	1

7. DATA REQUIREMENTS

Overlays of timber types by tone are desirable using a suitable map base e.g., U. S. quadrangle sheets. Tabulated statistics of area type should also be included.

8. INTERIM ACTIVITIES

Field work and aircraft studies should be conducted to establish the correlation of tone with forest species color before processing the data. This should be done at least one year in advance of the satellite operation to make possible intelligent data collection.

9. IMPORTANCE/JUSTIFICATION

This application would have a very high value, amounting to hundreds of thousands of dollars at the state and industry level, and millions for foreign governments in developing areas.

Location of new wood-using industries requires extensive surveys of available wood resources. In undeveloped areas where such plant location is increasingly important, pre-investment and investment surveys are needed.

10. SEOS UNIQUENESS

SEOS capability is not unique, but it is well suited to ensuring the necessary coverage of leaf color changes at the proper intervals.

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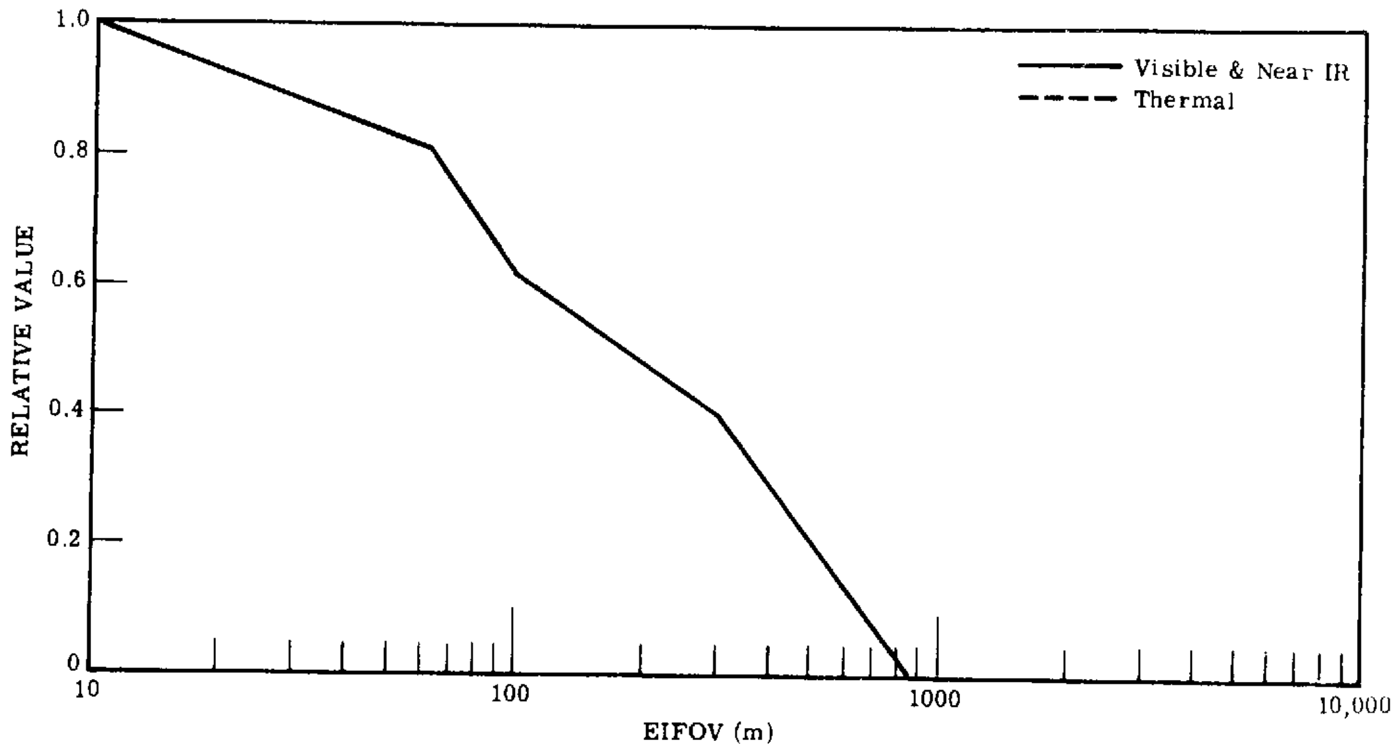
ΣERIM

SEOS APPLICATION SUMMARY

FOREST INVENTORY AND VALUATION FOR MULTIPLE-USE MANAGEMENT	APPLICATION	
U.S. Forest Service, State Departments of Natural Resources, National Park Service, Forest products industry, Natural Resource departments of foreign governments, Outdoor recreation industry, Food and agriculture organizations.	USER	
a) Foliage color reflection patterns prior to leaf fall. b) Pixel spectra; monitor end of growing season color change over a 1-2 month period.	OBSERVABLE AND CHARACTERISTICS	
End of growing season, fall in U.S. Sept., Oct.,	Season	TIME LINE OF EVENT
2 mo. Observation window: 7 days each species (not consecutive)	Duration	TIME LINE OF EVENT
1/yr	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
4	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
1 per 2 day interval for 2 mo., i.e. 30	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Some civil division e.g., county or management region	Geographic Location	SEOS OBSERVATION REQUIREMENTS
250 x 250 km	Dimensions (m., Km.)	
60 m. nominal, see attached graph	EIFOV (m.)	SENSOR REQUIREMENTS
.52-.56 μm .69-.75 .57-.59 .59-.62 .62-.68	Wavelength Interval (μm)	SENSOR REQUIREMENTS
1%	$\Delta\rho$, ΔT (%, ^{o}C)	SENSOR REQUIREMENTS
Overlays of timber types by tone for a suitable map base; e.g., USGS quad. sheets; tabulated statistics for areas of these types.	Format	DATA REQUIREMENTS
6 mos.	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Suitable map base; coordinates, time	Ancillary Data	DATA REQUIREMENTS
Establish specific color change characteristics of important species & their occurrence at least 1 yr. before data collection to insure intelligent mission planning (F,A/C).	Study	INTERIM ACTIVITIES
24 mm	Level	INTERIM ACTIVITIES
At least 1 yr. before satellite over-flight.	Time Frame	INTERIM ACTIVITIES
F/A/C	Platform	INTERIM ACTIVITIES
Hundreds of thousands of dollars at state levels; millions at foreign government level. Moderate to high.	IMPORTANCE/ JUSTIFICATION	
Not unique but optimally suited to insuring necessary coverage at proper intervals.	SEOS UNIQUENESS	



APPLICATION: Forest Inventory and Valuation for Multiple-Use Management

A6

EVALUATION OF RANGE FORAGE RESOURCES AND GRAZING PRESSURE ASSESSMENT

1. APPLICATION

Fifty to sixty percent of the total number of grazing animals in this country spend all or part of their lives on rangeland (Carneggie, et. al., 1967). The vegetation of this land is a resource with which managers are most concerned, because the annual forage and browse crop is converted by grazing animals, both domestic and wild, into useful animal products.

This forage crop, like an agricultural crop, should be harvested annually if it is to be utilized and provide benefit; but unlike an agricultural crop, forage production may be highly variable in amount from one season to the next because of variation in the amount and distribution of rainfall and in temperature regimes and because of previous management practices.

The forage crop in southwestern Arizona and southwestern New Mexico consists mainly of perennial grasses, mixed with browse species and annual grasses. These forage classes have different growth periods, and best use of the range results with seasonally shifting livestock utilization, matching the animals' preference for forage with a high nutritional level.

In late spring browse range furnishes the largest amount of forage. When summer rains begin, newly greening annuals are ideal forage. In the fall, as annuals dry; cattle can be shifted to ranges where perennial grasses are abundant (Reynolds and Martin, 1968).

Securing full use of the forage resource of grass-shrub ranges in the southwestern U. S. thus requires knowledge of the specific phenology of each of these critical forage crops. Observations would be used to aid livestock owners in determining when to shift cattle distribution to obtain maximum use of available forage while avoiding over-grazing a particular forage class.

2. USERS

USDA Statistical Reporting Service

USDA Forest Service

Bureau of Land Management

Bureau of Indian Affairs

Individual livestock owners and associations

Local management agencies

3. OBSERVABLE AND CHARACTERISTICS

For the grass-shrub range, there are three periods of about one month duration when amjor shifts in forage-class availability occur. At this time, species identification and measurement of plant density could provide the basis for rapid evaluation of range conditions to provide better estimates of potential carrying capacity and future fire hazard.

Sequential coverage of the range at a later stage of grazing may allow predictions to be made concerning the time remaing in the green feed period. It may also be possible to identify unique changes in reflectance phenomena associated with moderately to heavily grazed areas and thereby assess the extent of animal use.

Moisture conditions are particularly important on perennial ranges where adequate water may be a limiting factor in achieving optimum forage production. Repetitive observation of a site to monitor the soil mosture regime is thus also of value in determining the time and duration of optimum placement of stock.

The radiation observables of importance are foliage reflectance in the visible and near infrared regions, foliage temperature, and possibly radar signal return from soils. There is some possibility that moisture content in soils may be detected by a two-band radar, one band operating in the ¼ to 2 gigahertz range and the other operating in the 10 gigahertz range.

4. TIME LINE OF EVENTS/OBSERVABLE

The green period for the three most important forage classes occur in the late spring, midsummer and early fall. The period for greening of an individual forage class is perhaps one month in duration and observations must be critically timed within these highly dynamic periods.

5. SEOS OBSERVATIONAL REQUIREMENT

To determine the forage resource, one timely observation at each of the 3 critical periods is necessary. To estimate when grazing may begin for each forage class observations are required every three days. Monitoring grazing levels within a forage class could probably be done effectively at two week intervals. The geographic locations are civil divisions of southwestern U. S. A target size of 250 x 250 km would permit excellent synoptic coverage of the spatial relationships of range resources.

6. SENSOR REQUIREMENTS (See also table and resolution requirement figures)

	$\Delta\lambda$	$\Delta\rho$	$\%\Delta T$
MSS			
	.52-.56 μm	1%	
	.62-.68		
	.69-.75		
	1-1.4		
	1.5-1.8		
	2-2.3		Thermal is required.
	10.5-12.5		$1^{o}K$
RADAR	¼-2 gigahertz	S/N>1	
	10 gigahertz		

7. DATA REQUIREMENTS

Thematic maps of range forage abundance and utilization and moisture regime are needed for registration with topographic maps and land ownership information. Information on when to begin grazing is needed on a two day basis; forage potential information is needed in one week and range condition in two days after collection.

8. INTERIM ACTIVITIES

Interim activities include investigations of the basic biophysical relationship between grazing effects on a plant and the associated changes in reflectance. These should include ground, aircraft and ERTS studies. Good data must also be obtained on the relationship between rainfall and forage green-up.

Detailed study must be devoted to the feasibility of syntheticaperture radar systems operating from a geosynchronous satellite. This study must resolve many questions of power requirements, antenna size, adequacy of doppler signal for the needed resolution, relationship of signal return strength to soil moisture content, etc.

9. IMPORTANCE/JUSTIFICATION

Immediate benefits of over $50 million/year are not unforeseen, while wiser use of range resources will insure greater productivity over the long run as well.

10. SEOS UNIQUENESS

SEOS has a unique capability for determining the proper beginning of the grazing season over extensive areas because of the daily observation requirement.

In the other uses of potential forage estimation and grazing utilization, its contribution is not unique, but because of the short time involved in the former use, and sequential coverage required in the latter, it is well suited to these tasks as well.

LITERATURE CITED

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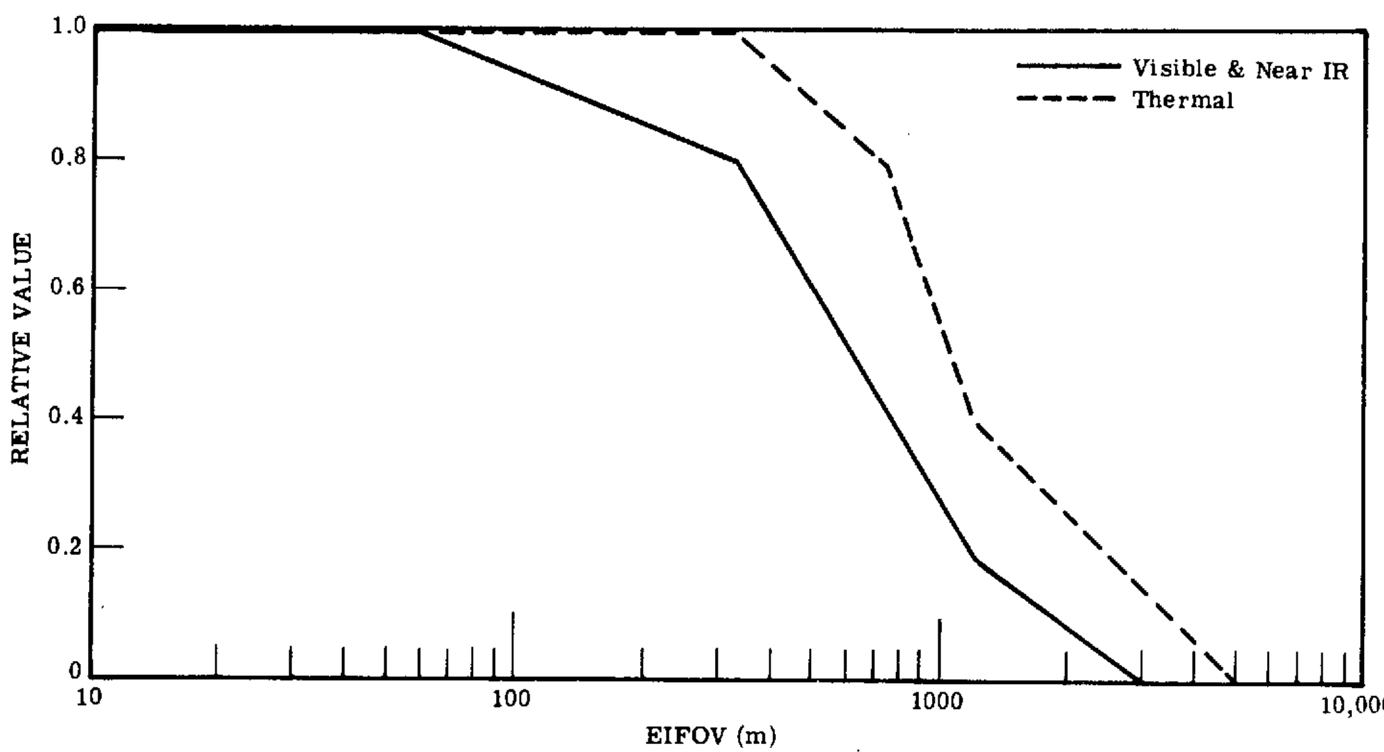
SEOS APPLICATION SUMMARY

ERIM

EVALUATION OF RANGE FORAGE RESOURCES AND GRAZING PRESSURE ASSESSMENT	APPLICATION	
USDA Statistical Reporting Service U.S. Forest Service Bureau of Land Management Bureau of Indian Affairs Individual livestock owners and associations Local management agencies	USER	
a) Annual greening of forage resource; reflectance phenomena associated with moderate or heavy grazing; soil moisture conditions. b) Pixel spectra; visible and NR reflectance at points in time and sequential change in these; radar return signal level.	OBSERVABLE AND CHARACTERISTICS	
Late spring; mid summer; early fall.	Season	TIME LINE OF EVENT
Four months total; 1 month critical period for each forage class. Observational window: 3 days.	Duration	TIME LINE OF EVENT
3 years	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
Depends on size of range or civil unit being inventorized ($\sim$2) For Ariz. & N.M.	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
3 day interval for 120 days ($\sim$40)	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Southwestern Arizona and Southeastern New Mexico.	Geographic Location	SEOS OBSERVATION REQUIREMENTS
250 x 250 km	Dimensions (m., Km.)	
Visible and NIR nominally 50 m. Thermal and Radar nominally 300 m. See attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
MSS — VIS: .52-.56 μm, .62-.68, .69-.75; NIR: 1-1.4, 1.5-1.8, 2-2.3; THERMAL: 10.5-12.5; RADAR: 1/4-2 Gigahertz, 10 Gigahertz. Thermal band is required.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
1% 1°K S/N>1	$\Delta\rho$, ΔT (%, °C)	SENSOR REQUIREMENTS
1) potential forage crop statistics 2) go/no go decision on when to graze 3) thematic maps of range forage abundance & utilization	Format	DATA REQUIREMENTS
1) 2 wks 2) 2 days 3) 2 days	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Topographic maps, land ownership data; location of major vegetation types.	Ancillary Data	DATA REQUIREMENTS
Investigate basic biophysical relationship between grazing effects on a plant & reflectance phenomena. Better define the moisture levels which yield particular radar responses (A.F. A/C, S/C)	Study	INTERIM ACTIVITIES
36 mm	Level	INTERIM ACTIVITIES
1975-1978	Time Frame	INTERIM ACTIVITIES
Ground/A/C/ERTS	Platform	INTERIM ACTIVITIES
50-50 million/year, Moderate	IMPORTANCE/ JUSTIFICATION	
Unique to optimum due to requirement for daily observation for extended periods.	SEOS UNIQUENESS	



APPLICATION: Evaluation of Range Forage Resources and Grazing Pressure Assessment

APPENDIX B

Land Use Survey and Mapping

B1
MANAGEMENT OF IRRIGATION

1. APPLICATION

Optimum timing, allocation, and application of irrigation water to crops for large regions.

2. USERS

U. S. Department of Agriculture
Local and regional water supply managers
Managers of irrigated farms

3. OBSERVABLE AND CHARACTERISTICS

Required information for determining the need for and timing of irrigation includes the monitoring of soil moisture content, detecting moisture stress in crops, and variations of growing schedules from normal. The effectiveness of the irrigation will be evident by observation of these same factors. The key to their reliable detection is careful measurement and preliminary "calibration" of farm areas to establish standard ranges of spectral and temporal signatures against which to compare specific conditions.

A promising method of measuring soil moisture content is to measure diurnal excursions of soil temperature. Moisture stress in crops might be detected by variations in vegetation signatures from expected or standard conditions. Variation of growing schedules as evidenced by changes in ground cover, maturation of crops, etc., might also be detected. Information needed for irrigation decisions could be made for individual farms and also for regional areas to optimize management of the available water supply. The effectiveness of the existing distribution systems will also be evident by correlating need with water availability. The amount of water supply is also predictable from SEOS data. In addition to irrigation timing and effectiveness, SEOS can be used to detect major leaks in the distribution system.

4. TIME LINE OF EVENTS/OBSERVABLE

Observation of an area should occur for those parts of the growing season in which irrigation decisions are made. During critical periods, a set of observations (soil moisture content, moisture stress, crop maturity) should be made twice a week. For soil moisture measurements, 4 to 8 observations in the 10.5 - 12.5 μm range are required during a 24-hour period. Moisture stress and crop maturity measurements can be based on a single set of two observations (mid-morning and mid-afternoon) in the visible and near-infrared range (0.5 - 1.5 μm).

5. SEOS OBSERVATIONAL REQUIREMENT

A SEOS demonstration should be conducted for four areas, each area representing a homogeneous sample in a single watershed of a particular type of agriculture based on irrigation practices. Each area should be about 2,000 sq km., although the exact size is not critical. The first year of the SEOS experiment would be devoted to collecting information on spectral, thermal and temporal signatures and relating these to conditions observed on the ground. During the second and third years, this basic information would be applied to SEOS data to arrive at management decisions concerning the need for irrigation, and proper timing and application.

6. SENSOR REQUIREMENTS

For areas in which large farms predominate, 100 m would be adequate resolution. For smaller farms (e.g., 40 acres in size) resolution of 50 m would be required for adequate observation. The value of $\Delta\rho$ should be 1%, and the value of ΔT should be 2°C. Temperature measurements should be made in the 10.5 - 12.5 μm range, vegetation signature measurements in the visible and near-IR range (five bands located between 0.5 - 1.5 μm). Thermal band is required.

7. DATA REQUIREMENTS

Soil temperature measurements and spectral signature data should be provided both in the form of images and computer compatible tape. Extensive ground-based measurements and aerial survey of sample areas will be required for the first year of the experiment. During the prototype operation period, less extensive measurements will be required, primarily for calibration and validation of the satellite data. Management data in the form of maps showing relative water needs should be available within 24 hours of data acquisition.

8. INTERIM ACTIVITIES

The feasibility of soil moisture measurement by observation of diurnal temperature requires development and demonstration. For moisture stress detection and crop maturity observations, past work in spectral signature analysis should be reviewed to determine sensitivity and reliability of the methods. In particular, results of ERTS experiments related to this application should be monitored.

9. IMPORTANCE/JUSTIFICATION

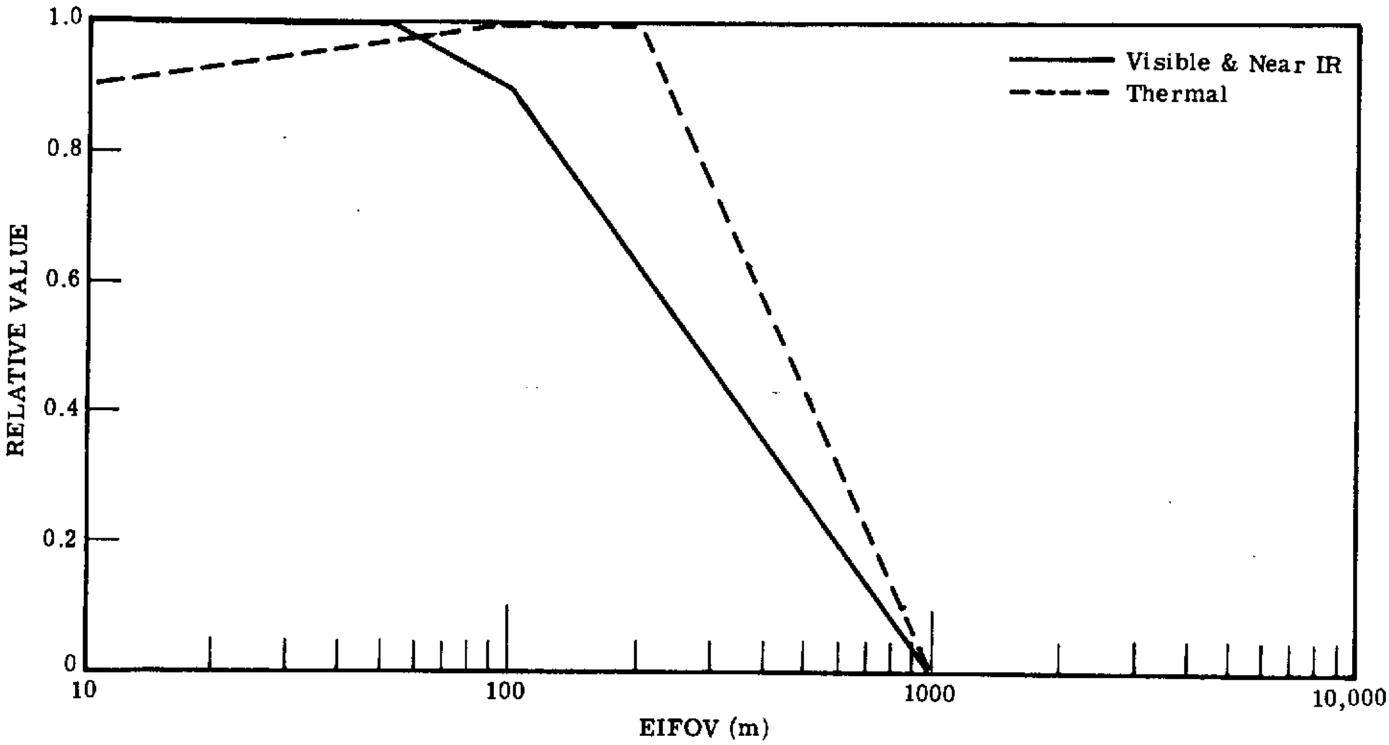
Heavy demands for our limited water resources require that we make optimum use of the water available for irrigation. Improved streamflow prediction through monitoring of snow inventory, as described in another application, is one approach to this problem. The approach discussed here is that of monitoring the need, timing, distribution, and application of irrigation waters. Accomplishing this management for individual farms and also on a regional basis would further increase the effectiveness of the procedure.

10. SEOS UNIQUENESS

A limited capability for this application exists with a combination of aircraft and ERTS observations. However, ERTS is limited by the large intervals likely to occur between repeated observations of the operational area. SEOS would greatly increase this capability through its ability to make diurnal measurements and its ability for critical timing of observations.

SEOS APPLICATION SUMMARY

MANAGEMENT OF IRRIGATION	APPLICATION	
U. S. Department of Agriculture Local and Regional Water Supply Managers Commercial farmers.	USER	
Moisture Stress; soil moisture content; phenology. Diurnal temperature variations, crop density; geometry and albedo.	OBSERVABLE AND CHARACTERISTICS	
Spring and summer	Season	TIME LINE OF EVENT
Observation window: 1 hour. 4 mo./year observations at 3 hour intervals 1 day each week.	Duration	TIME LINE OF EVENT
1 per week	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
4	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
Observations at 3 hour intervals 1 day each week.	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Central and Midwest U.S.	Geographic Location	SEOS OBSERVATION REQUIREMENTS
50 km x 50 km	Dimensions (m., Km.)	
50 m. optimum 200 m. optimum See attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
5 M-S bands 0.5-1.5μm 10.5-12.5 μm Thermal band is required.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
$\Delta\rho$ = 1% ΔT = 2°C	$\Delta\rho$, ΔT (%, °C)	SENSOR REQUIREMENTS
Imagery and computer compatible tapes. Maps of relative need.	Format	DATA REQUIREMENTS
2 days	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Soil moisture, crop relative turgidity; transpiration rate, vegetative temperatures.	Ancillary Data	DATA REQUIREMENTS
Soil moisture/veg. stress/signature definition (A,F).	Study	INTERIM ACTIVITIES
36 mm	Level	INTERIM ACTIVITIES
1974-1975	Time Frame	INTERIM ACTIVITIES
ERTS and field based spectral and temporal data.	Platform	INTERIM ACTIVITIES
High	IMPORTANCE/ JUSTIFICATION	
Optimum	SEOS UNIQUENESS	



APPLICATION: Management of Irrigation

B2
WILDFIRE DETECTION

1. APPLICATION

This application is concerned with early detection of wildfires in economically important forest and rangeland area.

In 1963, over 145,000 wildfires burned over 7,120,000 acres in the U.S., of which 3,317,000 acres were lands under federal, state or private fire protection. The annual expenditure for the detection and fighting of fires ranged from $150-200 million and the annual loss from these fires has been estimated at between $50-300 million.

Project FIRESCAN, the U.S. Forest Service's thermal scanning aircraft project, has been instrumental in reducing these figures through its timely detection of beginning fires. The effectiveness of this program, though, is limited by the flight range and excessive time aloft needed for the aircraft to provide coverage of potential wildfire areas and the means for identifying fires under control. A satellite system would be able to provide large area coverage on a timely repetitive basis with computers storing the location of friendly fires.

2. USERS

U.S. Forest Service
Bureau of Land Management
Bureau of Indian Affairs
National Park Service
Canadian Forestry Service
State Department of Natural Resources
Timber companies

3. OBSERVABLE AND CHARACTERISTICS

Detection of forest fires could be performed most effectively in the thermal region. Initial detection and warning capabilities could be provided by the use of a bi-channel target discrimination module similar to that currently used by the U.S. Forest Service (S.N. Hirsch, et al, 1971), operating in the 3-4 μm and 8.5-11 μm thermal regions. (These bands for a spaceborne sensor would be shifted to 3.4-4.1 μm and 10.5-12.5 μm). Detection of larger fires could be accomplished by recognition of smoke plumes, as shown on current ERTS imagery in the visible spectral region.

4. TIME LINE OF EVENTS/OBSERVABLE

In an operational demonstration system, year-round imaging on a daily basis of all fire-prone areas (forest, savannahs, grasslands) would be desirable but not necessary. Most wildfires in a given region are seasonal. For example, the forests of western North America are prone to fires from June in the southwest to September and October in the northwest and Canada. Detection scanning should be concentrated on an area as it reaches its peak fire season. In order to demonstrate the usefulness of the system, two different test sites are proposed: (1) the grasslands and forests of southern California, and (2) the forests of the Northwest. Each remains a high risk area for one to two months, and the time periods would be consecutive.

5. SEOS OBSERVATIONAL REQUIREMENT

In order to be of significant use as a wildfire detection system, SEOS would have to provide daily or more frequent coverage of the high-risk test regions. This could include an area as much as 500,000 sq km or more. Extensive scanning time would be required, but this might not be a drawback, as much of this operation could take place at night. Provision must be made to distinguish wildfires from those under control. Repetitive viewing and change detection could supply data of this nature.

6. SENSOR REQUIREMENTS

λ	$\Delta\rho:\Delta T$	EIFOV
0.5-1.4 μm	2%	100 m. nominal
3.5-4.1 μm	10°C	100 m. nominal
10.5-12.5 μm	10°C	100 m. nominal

A larger FOV with increased sensitivity (smaller ΔT) in the thermal channels may be acceptable, but the permissible size requires further study. The FOV of the current Forest Service scanner operated at around 18,000 ft altitude is 10 m. Thermal bands are required.

7. DATA REQUIREMENTS

Terrain imagery with the identified fires marked should be available to Forest Service personnel within an hour for valid fire detection use. The information can then be verified by aircraft overflight and/or fire-fighter crew dispersal.

8. INTERIM ACTIVITIES

Study is needed in defining the EIFOV and temperature sensitivity combination needed for detection of "small" wildfires or to delineate the minimum size fire detectable with satellite capabilities. The target discrimination model should also be refined and made satellite-compatible. The operation of a thermal sensor or sensors in planned ERTS-2, other satellites and/or high altitude aircraft, would allow testing of resolution capabilities and examination of atmospheric attenuation and other variables.

A 24 man month effort in the spring and summer of 1975 and 1976 is proposed for analytical and field study of signatures and detection models.

9. IMPORTANCE/JUSTIFICATION

Early detection and consequent control of wildfires could save hundreds of thousands of acres of valuable timber and rangeland each year in the United States alone. As little as a 2-3% reduction in acreage burned in the U.S. would amount to a savings of over $2 million. Extension of the detection coverage to Canada, Central America, or to most major world areas, would add increasing benefits. Benefits would be measured not only in terms of timber volume or rangeland saved, but in the value of recreation areas protected and reduced costs for conventional fire detection and control.

Impact of a successful program would be high and of international benefit if coverage is extended beyond the U.S.

10. SEOS UNIQUENESS

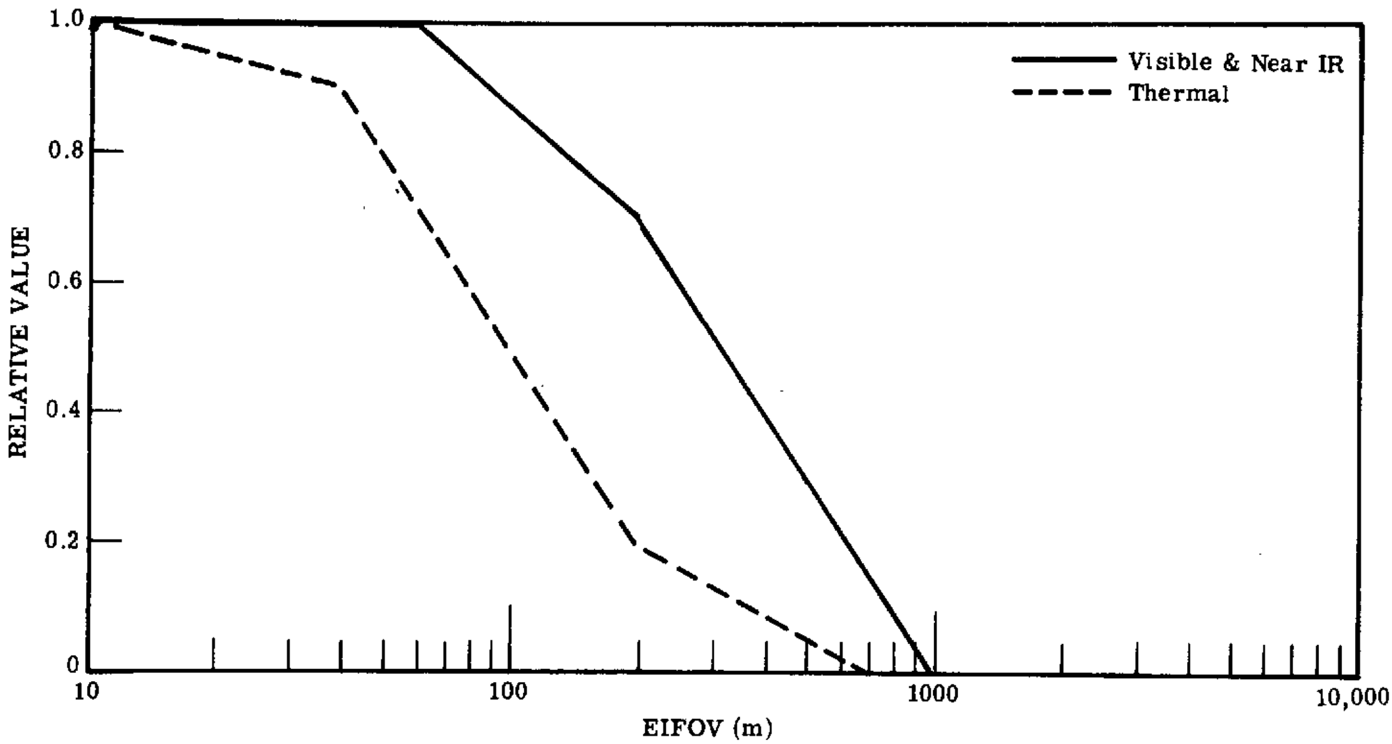
SEOS has the unique capability of offering continuous or near-continuous coverage of an area, which is necessary for useful detection of wildfires. It would be better and more efficient than conventional methods, in terms of extent, reliability and timeliness of coverage. Its usefulness depends, however, on the ability to achieve the necessary and as yet undefined sensor resolution, detection, and total coverage capabilities.

LITERATURE CITED

Hirsch, S.N., R. F. Krunkeberg, and F. H. Madden. 1971. The Bi-spectral forest fire detection system. Seventh Symposium on Remote Sensing of Environment, The University of Michigan.

SEOS APPLICATION SUMMARY

WILDLIFE DETECTION	APPLICATION	
U. S. Forest Service, Bureau of Land Management, Bureau of Indian Affairs, National Park Service, Canadian Forestry Service, State Departments of Natural Resources, Timber companies.	USER	
Heat, intensity and level above ambient. Smoke.	OBSERVABLE AND CHARACTERISTICS	
Spring through fall.	Season	TIME LINE OF EVENT
2 optimum months; observation window: 1 day.	Duration	
2	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
1	No. Targets per Event	
1/day for 2 mos.	No. Observ. per Target	
U. S. (California and Pacific Northwest).	Geographic Location	
Up to 10^6 km^2	Dimensions (m., Km.)	
Visible and NIR nominally 70 m.; thermal nominally 10m; See attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
.52-.56μm 3.5-4.1 μm .62-.68μm 10.5-12.5 μm 1.0-1.4 μm Thermal bands are required.	Wavelength Interval (μm)	
$\Delta\rho$ = 2% ΔT = 10°C	$\Delta\rho$, ΔT (%, °C)	
Imagery; annotated maps.	Format	DATA REQUIREMENTS
1 hr.	Time After Observ. (Da.Wk.Mo.)	
Fuel conditions, weather forecasts, meteorological conditions, local topography.	Ancillary Data	
Analytic and field study of signature and detection model (A,F,A/C,S/C)	Study	INTERIM ACTIVITIES
24 mm	Level	
Spring and Summer 1975-1976	Time Frame	
Field, A/C, ERTS	Platform	
High	IMPORTANCE/ JUSTIFICATION	
Unique to Optimum due to requirement for daily observation over extended period.	SEOS UNIQUENESS	



APPLICATION: Wildfire Detection

B3
WILDFIRE MONITORING

1. APPLICATION

This application is concerned with monitoring and control of wildfire in economically important forest and rangeland areas.

In 1963, over 145,000 wildfires burned over 7,120,000 acres in the U.S. of which 3,317,000 acres were lands under federal, state, or private fire protection. The annual expenditure for the detection and fighting of fires ranged from $150-200 million and the annual loss from these fires has been estimated at between $50-300 million.

Project FIRESCAN, THE U.S. Forest Service's thermal scanning aircraft project, has been instrumental in reducing these figures through timely detection of beginning fires. Continuous fire monitoring from aircraft, however, is difficult and dangerous. Yet the need for a complete uninterrupted history of a fire is often as great as that of its detection (Bjornsen, R. L., 1968). Much of the fire dynamics can be inferred from analysis of its convective activity and total heat budget.

During the suppression effort, it is of major importance that the instantaneous perimeter and internal detail of the fire be correlated with weather and terrain information to determine its potential spread.

Following the fire, ecologists can plan the future management of the burned-over site far more effectively if they have knowledge of the fire's local severity, i.e., its intensity and duration (Pearson, et al, 1972; Kreese, 1972). In many cases, they can then determine whether artificial restocking of the vegetation is necessary, or if the natural vegetation has a chance for survival or regeneration. As might be imagined, these items have major implication in watershed and wildlife management.

2. USERS

U.S. Forest Service
Bureau of Land Management
Bureau of Indian Affairs
National Park Service
Canadian Forestry Service
State Department of Natural Resources
Timber companies

3. OBSERVABLE AND CHARACTERISTICS

An imaging system in the 3.5-4.1 μm and 10.5-12.5 μm thermal regions could be used to monitor burning fires. The first channel would map the internal isothermal regions of the fire and its perimeter. The second, ambient channel would provide terrain imagery for locating the fire perimeter and correlating fire characteristics with local topography (Hirsch, et al, 1971).

Lower spatial resolution data would also provide useful information concerning the dynamics of the fire. Visible imagery of the rising smoke would allow a study of the convective activity. Radiometric thermal data with resolution of the order of 2 miles would yield good estimates of the fire's areal extent. This data together with ground observations on the size of the fire perimeter will provide vital information as to whether or not the fire is growing or under control.

4. TIME LINE OF EVENTS/OBSERVABLE

In an operational system, year-round imaging capability of all fire-prone areas (forest, savannahs, grasslands) would be desirable. However, most wildfires in a given region are seasonal. For example, the forests of western North America are prone to fires from June in the southwest to September and October in the northwest and Canada (Fischer, 1969).

Monitoring of fires would most likely be needed in an area during its peak fire season. Each event would last from 2 days to a week.

5. SEOS OBSERVATIONAL REQUIREMENTS

Monitoring of fires in progress would be a random event both geographically and temporally. In an applications demonstration program, at least three should be monitored, to represent both grassland and forest situations. California and the Pacific Northwest would provide prime target areas. Continuous or near continuous detailed imaging of each fire would be desirable; however, coverage of dusk and dawn only would still be of great value. Target dimensions are variable, but a nominal size of 15 x 15 km may be assumed. Mapping the areal extent of damage after a fire would require only one good "look" at each area.

6. SENSOR REQUIREMENTS

λ	$\Delta\rho:\Delta T$	EIFOV
0.5-1.5 μm	2%	100 m. nominal
3.5-4.1 μm	10°C	100 m. nominal
10.5-12.5 μm	10°C	100 m. nominal

Considerably larger EIFOVs may be acceptable for monitoring the convective plume and heat budget (200 meters for the reflective band and 5 km for the thermal bands). Thermal bands are required.

7. DATA REQUIREMENTS

Large scale imagery of fires already burning would be needed within a few hours time for use by the first fire crews. This would be backed up by current aircraft and ground mapping procedures.

Information needed at the fire site includes instantaneous TV display of the internal isothermal regions of the fire, its perimeter, and the surrounding terrain. A capability for periodically generating hard copy from this display is also desirable. Data in the visible region could also be displayed to show local weather patterns. All data should be recorded for later review and assessment.

8. INTERIM ACTIVITIES

Study is needed in defining the EIFOV and temperature sensitivity combination needed for mapping wildfires. The operation of a thermal sensor or sensors in planned ERTS-2, other satellites and/or high altitude aircraft, would allow testing of resolution capabilities and examination of atmospheric attenuation and other variables. A study to develop communication linking equipment and the portable on-site display capability is also needed.

A 24 man month effort in the spring and summer of 1975 and 1976 is proposed for analytical and field study of signatures and attenuation models.

9. IMPORTANCE/JUSTIFICATION

Monitoring of fires to aid in putting them under control will save valuable acreages. Benefits would be measured not only in terms of timber volume or rangeland saved, but in the value of recreation areas protected and reduced costs for conventional fire detection and control.

Impact of a successful program would be high and of international benefit if coverage is extended beyond the U.S.

10. SEOS UNIQUENESS

SEOS has the unique capability of offering continuous repeated coverage of an area, which is necessary for fire monitoring. It would be better, safer, and more efficient than conventional methods, in terms of reliability and timeliness of coverage, especially with a direct TV display capability. Its usefulness depends, however, on the ability to achieve the necessary sensor resolutions.

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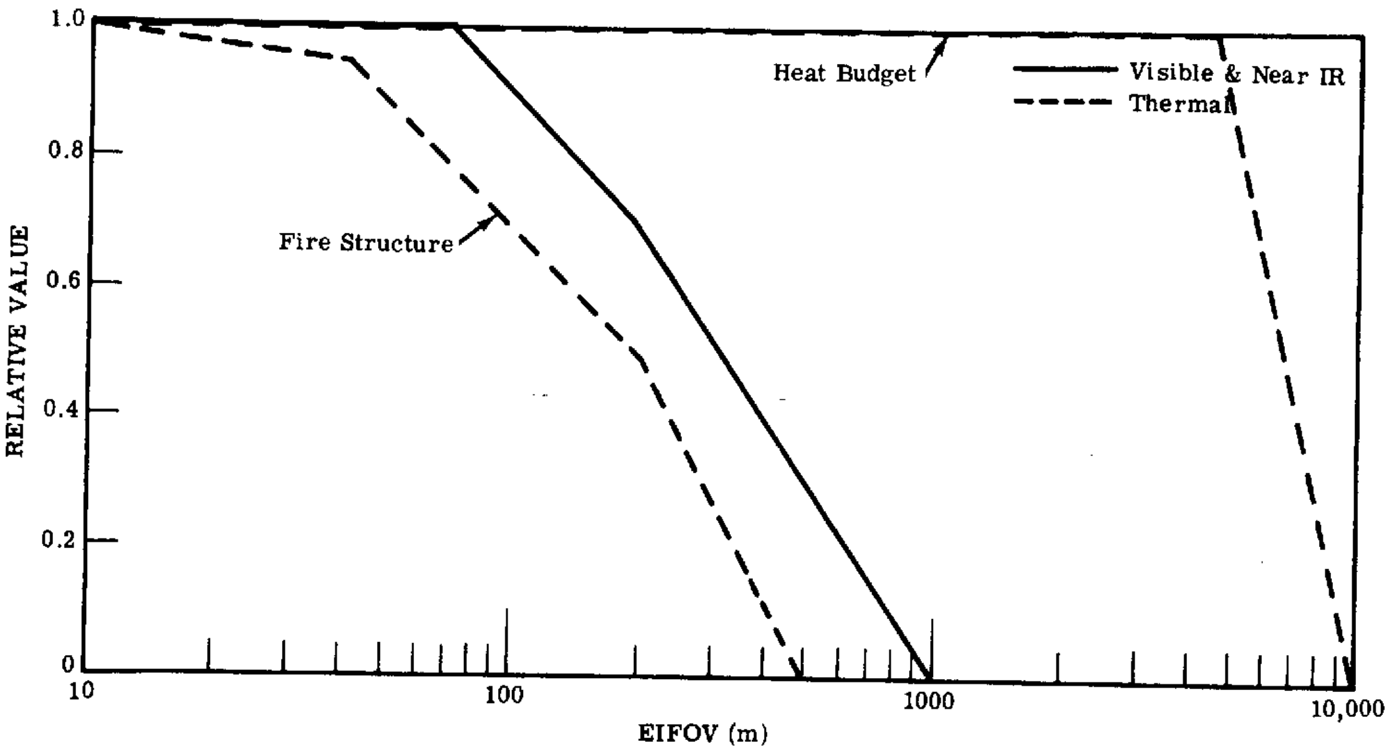
SEOS APPLICATION SUMMARY

ERIM

WILDFIRE MONITORING	APPLICATION	
U.S. Forest Service, Bureau of Land Management, Bureau of Indian Affairs, National Park Service, Canadian Forestry Service, State Departments of Natural Resources, Timber Companies.	USER	
Smoke and heat, reflection and thermal emission, Intensity and spatial pattern. Fire perimeter and internal structure.	OBSERVABLE AND CHARACTERISTICS	
Spring through Fall.	Season	TIME LINE OF EVENT
Observation window: Instantaneous Duration: 2-7 days each.	Duration	TIME LINE OF EVENT
3	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
6	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
12	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
U.S. (California and Pacific Northwest)	Geographic Location	SEOS OBSERVATION REQUIREMENTS
1.5 x 1.5 km	Dimensions (m., Km.)	
Visible and NIR 200 m. nominally; thermal 100 m and 6km. See attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
.52-.56μm 3.5-4.1μm .62-.68μm 10.5-12.5μm 1.0-1.4 μm Thermal bands are required	Wavelength Interval (μm)	SENSOR REQUIREMENTS
$\Delta\rho$=2% ΔT-10°C	$\Delta\rho$, ΔT (%, °C)	SENSOR REQUIREMENTS
Imagery; annotated maps, on site TV display.	Format	DATA REQUIREMENTS
Monitoring instantaneous (< 5 min)	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Fuel conditions, weather forecasts, meteorological conditions, local topography.	Ancillary Data	DATA REQUIREMENTS
Analytic and field study of signatures. Equipment development for display and readout (A,F, A/C, S/C)	Study	INTERIM ACTIVITIES
24 mm	Level	INTERIM ACTIVITIES
Spring and summer 1975-1976	Time Frame	INTERIM ACTIVITIES
Field/A/C/ERTS	Platform	INTERIM ACTIVITIES
High	IMPORTANCE/ JUSTIFICATION	
Unique to Optimum.	SEOS UNIQUENESS	



APPLICATION: Wildfire Monitoring

B4
THEMATIC MAPPING

1. APPLICATION

The special characteristics of SEOS can be used for more detailed and accurate mapping of land use and natural resources. SEOS techniques described below would apply not only to mapping of land use and land cover, but could be extended to special applications such as plant disease detection, crop forecasting, or mineral exploration. However, this section is confined to a discussion of thematic mapping with special reference to land use and natural resource mapping.

The use of the techniques described herein for improved thematic mapping would have an important application in the mapping of large regions, following such classification systems as described in (Anderson, et al., 1972). It is presently estimated that ERTS-1 imagery will be effective in separating land use into most Level I classes and some Level II classes. The special techniques available with the use of SEOS could increase the ability to classify land use according to Level II and even into some types of Level III classes.

2. USERS

U. S. Geological Survey
Bureau of Land Management
Bureau of Outdoor Recreation
Department of Agriculture
U. S. Forest Service
State Departments of Natural Resources
State Highway Departments
State and regional planning agencies
Zoning and enforcement agencies

Real estate development agencies

Timber companies

3. OBSERVABLE AND CHARACTERISTICS

Under existing ERTS and EREP investigations, recognition mapping is being developed to make use of spectral discrimination, temporal discrimination of seasonal changes of vegetation, spatial discrimination of gross surface texture, stereoscopic analysis, and low sun angle viewing of macro-relief. This capability is enhanced by the development of methods of accurate registration of multiple frames.

SEOS would increase the ability to discriminate various types of terrain, relief, vegetation, urban areas, etc., by providing a capability for measuring a variety of characteristics not possible with ERTS. Diurnal variations of surface temperature would discriminate surfaces of differing thermal emissivity, conductivity or inertia. Diurnal variations in sun angle would produce shadow which yield radiance variations associated with building height, or vegetation height and structure. Mapping of night lighting would delineate urban boundaries. Variations in viewing angle would enhance spectral discrimination of soil and rock types, vegetation, and man-made structures. The ability to use SEOS for quick-reaction observation of specific areas would further increase this discrimination capability. Flexible timing of observations to take advantage of cloud-free periods would make possible controlled observation of vegetation color changes, enhancement of surface features by light snow cover and differential melting rates, and accurate delineation of flood plains.

Seasonal Changes

Differentiation of vegetation type or condition would be possible from carefully-timed observation of seasonal or annual changes which affect the fraction of vegetative ground cover, the changing structure or color of the vegetation as it grows and matures, and the harvesting of the crop (Richardson, et al., 1972). Such observations from SEOS would provide information useful for distinguishing cropland in active use from pasture or idle agricultural land. In the case of forestland, the differentiation may be based on time of leaf flush, fall color change, and leaf fall. The contribution of SEOS to these observations is its ability to observe these seasonal changes at optimum times with minimum restriction from the observation windows of lower altitude satellites. Significant changes which materially aid in the identification process sometimes persist for only a few days.

Diurnal Temperature Changes

Diurnal excursions of surface temperature have been shown to be useful for observing differences in urban and rural climate (Pease, 1971), differentiating land from water areas, indicating soil moisture content and estimating depth of snow and sea ice (Horvath and Lowe, 1968). Variations in thermal characteristics could be used to discriminate various natural or construction materials, such as concrete, asphalt, bare soil, roofing materials irradiated by sunlight, or roofing materials covering heated areas. Diurnal variations of temperature might also be used to discriminate types of vegetation with similar spectral characteristics but differences in height, structure, density, or ground cover. Different types of rock and soil can also be discriminated by variations of thermal characteristics.

View Angle and Sun Angle Variations

The ability to observe terrain surfaces from various elevation angles of viewing and illumination angles is a sensitive indicator of vertical structure. At low sun angles or view angles, the uppermost surfaces are the areas primarily observed by the sensor, while at high sun angles or high view angles, the sensor observes a combination of both higher and lower parts of the structure. These differences in emphasis of various horizontal layers of vegetated surfaces, urban structure, terrain relief, etc., would add to the signature information from spectral, temperature or other phenomena to increase the ability to differentiate and identify various types of surfaces. Of particular interest is the possibility of using the "hot spot" effect which occurs when the view angle and sun angle are identical within a degree or two. Under this condition, reflection of sunlight from the lowest layers of the vegetative or other structure will reach the sensor from which information on the geometry, density or condition of the lower layers can be inferred to aid in their identification.

Theoretical and experimental work is presently being performed jointly by ERIM and Michigan State University personnel to develop the scientific basis for this type of interpretation. This work includes the development of analytical models of vegetation canopies (Suits, 1972a; Suits, 1972b) and experiments to demonstrate spectral differences of scenes observed from various view angles.

In (Suits, 1972a), a model is developed for calculation of the directional reflectance of a multilayer vegetative canopy. This model indicates that the directional reflectance of a given type of vegetation will show distinct variations with respect to view angle and sun angle which are dependent on its physical structure at various horizontal layers. Thus, observation at various combinations of view angle and illumination can provide increased information for improved recognition of vegetation classes. In (Suits, 1972b), the analysis of vegetative canopies is extended to account for effects which result from variations of angle between viewing azimuth and illumination azimuth. The introduction of azimuthal variations further increases the basis for distinguishing various types of vegetation. In addition, it could be of significant value in identifying row crops or orchards, which have distinct changes in spectral character depending on the direction from which these fields are views.

Specific applications to thematic mapping of vegetation would include improved discrimination of vegetation types on the basis of composition of forest understory, and variations in vegetation height or density. Thematic mapping of urban areas could be improved by differentiating areas of substantially different building height or density on the basis of shadow effects, and distinguishing ratio of tree cover to lawn cover in residential or park areas.

4. TIME LINE OF EVENT/OBSERVABLE

Events and observables as described above are extremely diverse. Surface temperature, sun angle, and view angle must be observed over the diurnal cycle. Observation of vegetation color changes, light snow cover, and flood extent may occur over short intervals at various seasons and reaction must be accurately timed and correlated with available clear viewing conditions.

5. SEOS OBSERVATIONAL REQUIREMENTS

For a valid SEOS experiment, a variety of test sites are needed representing various types of land use, e.g., major crops, coniferous forest, deciduous forest, and urban areas. An effective experiment could be conducted using 15 types of land use or land cover. Test site for each type should be 2 km x 2 km, with the individual sites preferably in close proximity to each other to permit common use of a single image frame, ground truth activities, etc. For diurnal observations, 4 to 8 observations over a 24-hr period are needed. For quick reaction observations, one or two precisely timed observations are needed.

6. SENSOR REQUIREMENTS

Resolution of images for effective land use mapping should be at least 200 m or better.

EIFOV	$\lambda;\Delta\lambda$	$\Delta\rho;\Delta T$
200 m	5 bands spread through range of 0.5 - 2.0 μm	$\Delta\rho = 2\%$
400 m	10.5 - 12.5 μm	$\Delta T = 2°C$
		Thermal is required.

7. DATA REQUIREMENTS

Data should be provided as imagery for three representative bands, including a thermal band. For analysis, data should also be provided as computer-compatible magnetic tape. Auxiliary information should include time of observation, view angles, and sensor calibration data. Data are desired within 1 month of a completed observation.

8. INTERIM ACTIVITIES

Experiments should be conducted to collect and analyze reflective signatures and thermal data on selected terrain surfaces for the variety of conditions listed above. The objective is to define those variables which are most useful for improved discrimination of these surfaces, and excursions of reflectivity or temperature available for use. Emphasis should be placed on types of surface where improvements in surface discrimination beyond ERTS capabilities are required. The data should be provided by airborne and ground-based spectral and thermal measurements. Further analysis is also required of the range of sizes of homogeneous areas of land use or land cover. This research effort should begin in 1974 and extend for a period of 2 years.

9. IMPORTANCE/JUSTIFICATION

ERTS presently promises to be very useful for widespread mapping of land use and land cover. It presently appears that it will be capable of identifying and mapping most types of Level I land use categories and some types of Level II categories. The special capabilities of SEOS would extend this discrimination capability to permit finer differentiation of significant land use categories, such as different types of residential, commercial or industrial land use, tree or crop species or maturity, soil or rock types, wetland classification and extent, landforms and macrorelief.

The ability of SEOS to provide reliable repetition of coverage at monthly intervals would also be advantageous for noting significant changes in urban areas with minimum delay.

10. SEOS UNIQUENESS

SEOS capability can be approximated by the use of the ERTS system under favorable circumstances, but SEOS will maximize this capability through its ability to obtain repeated coverage of selected areas over a diurnal cycle or by precision timing over a period of several days. This is important for discrimination of terrain variables on the basis of physical or biological factors which change rapidly with time.

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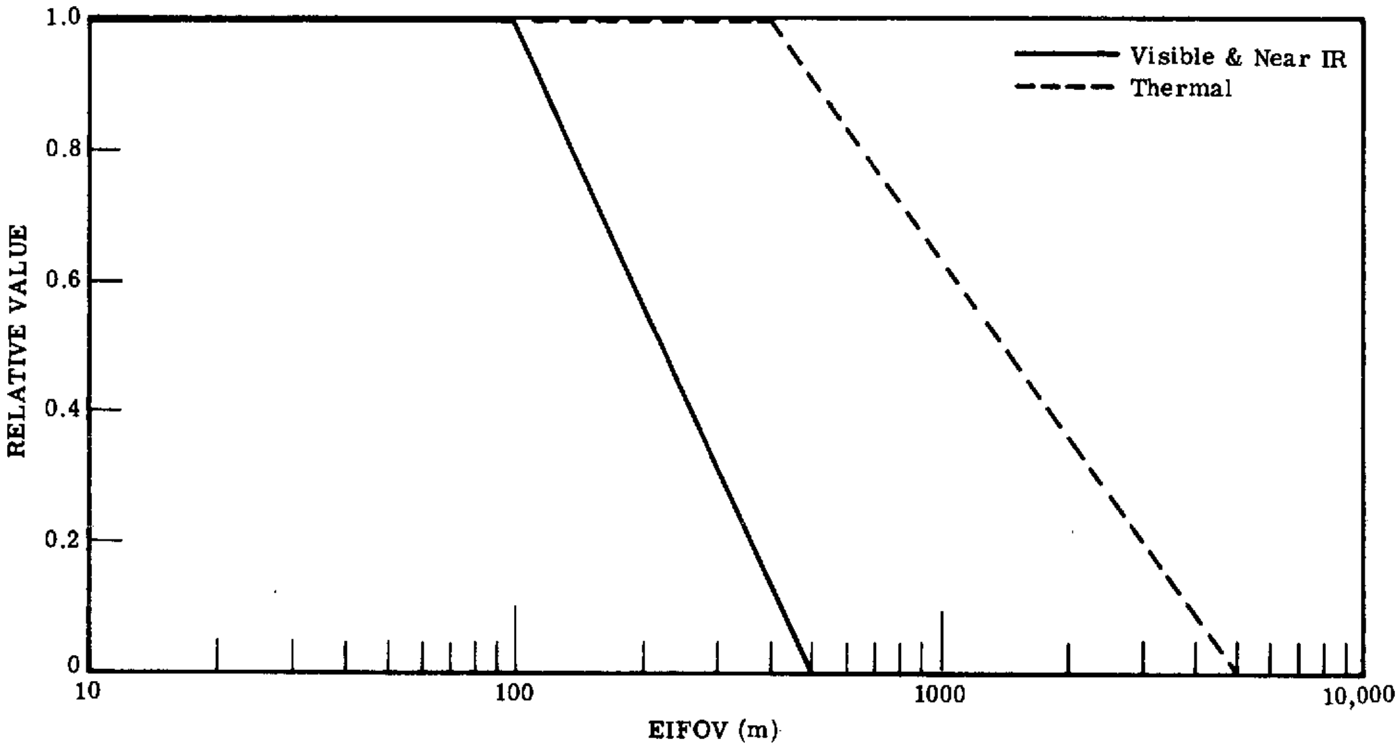
SEOS APPLICATION SUMMARY

ERIM

THEMATIC MAPPING	APPLICATION	
U.S. Geological Survey; State Departments of Natural Resources; Bureau of Land Management; State Highway Departments; Bureau of Outdoor Recreation; Timber Companies; State and Regional Planning Agencies; Department of Agriculture; U.S. Forest Service; Zoning and Enforcement Agencies; Real Estate Development Agencies	USER	
1) Diurnal temperature changes. 2) Critically timed observations of seasonal changes. 3) Observations under varying view angles and sun angles.	OBSERVABLE AND CHARACTERISTICS	
All	Season	TIME LINE OF EVENT
1 year. Observation over 4 five-day intervals. Observation window: one hour.	Duration	TIME LINE OF EVENT
4	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
15	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
8 Observations at 3 hour intervals for five-day periods (40)	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Suggest Michigan for variety of sites and proximity.	Geographic Location	SEOS OBSERVATION REQUIREMENTS
2 km x 2 km	Dimensions (m., Km.)	
Visible and NIR 200 m., nominal; Thermal 400 m. nominal; see attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
5 bands in 0.5-2.0 μm range. 10.5 - 12.5μm Thermal band is required.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
$\Delta\rho$=2% ΔT≈2°C	$\Delta\rho$, ΔT (%, °C)	SENSOR REQUIREMENTS
Imagery and computer compatible tape.	Format	DATA REQUIREMENTS
1 mo. (not critical)	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Time of observation, view angles Ground based Spot checks	Ancillary Data	DATA REQUIREMENTS
Spectral/temporal signature definition (F,A/C)	Study	INTERIM ACTIVITIES
48 mm	Level	INTERIM ACTIVITIES
1974-1975	Time Frame	INTERIM ACTIVITIES
Field and A/C Spect. Meas.	Platform	INTERIM ACTIVITIES
High	IMPORTANCE/ JUSTIFICATION	
Optimum, due to requirement for critically timed diurnal observations.	SEOS UNIQUENESS	



APPLICATION: Thematic Mapping

APPENDIX C

Mineral Resources, Geological, Structural and Landform Survey

C1

EXPLORATION FOR GEOTHERMAL SOURCES

1. APPLICATION

Natural heat of the earth, geothermal energy, has the potential of producing cheaper, more pollution-free energy than hydroelectric, hydrocarbon-burning, and nuclear power sources (Rex, 1971). Though some other countries, such as New Zealand, Iceland, Italy, and Mexico, are considered ahead of the United States in exploiting geothermal energy, new federal monies are being applied to the development of geothermal power plants. Since geothermal energy cannot be effectively transported long distances, power plants and hot-water heating systems for homes and other buildings must be located in the vicinity of the geothermal source. Hence, exploration for geothermal sources is important, not only from the standpoint of the requirement for greater total energy production, but also from the need for finding energy sources near the consumer wherever possible.

Exploration methods for geothermal sources is analogous to that of the petroleum industry in the nineteenth century (Summers, 1968), when developers were drilling for oil only at the surface seeps. Currently, the known geysers and hot springs are being drilled for natural steam. As of 1968, only one steam field had been discovered that was not marked by surface heat manifestations (McNitt, 1968). However, several exploration methods have been employed, with varying degrees of success. They include such geophysical methods (Bowen and Groh, 1971) as measuring thermal gradient from ground thermometers deployed over a regional exploration grid, ground resistivity measurements, infrared surveys, gravity and magnetic surveys, and seismic measurements. These have been more helpful in defining the extent of known geothermal areas more clearly than in finding new sources, thus far. Geochemical indicators, such as higher silica content in water from hot springs and geysers and large amounts of alternation products near these sites, have been useful for both exploration and modeling the underground temperature gradient.

2. USERS

U. S. Department of Interior
Atmoic Energy Commission
State Geologic Surveys
Power companies
Land development companies
Construction industry

3. OBSERVABLE AND CHARACTERISTICS

Surface temperature and temperature patterns, along with diurnal and seasonal changes, as influenced by subsurface sources and conduction are the key observables.

4. TIME LINE OF EVENT/OBSERVABLE

The infrared surveys of geothermal areas have thus far been limited to aircraft, which usually cover the test sites one or two times each. However, if new geothermal areas that have no visible surface expression are explored, it is likely that the surface temperature would be only slightly altered as a result of the geothermal source, which would require studying thermal temporal changes over a period of several days, at observation periods on the order of every four hours. This frequency and duration of observation would be required to permit the separation of diurnal illumination and meteorological effects from effects due to internal heat sources and thermal inertia.

5. SEOS OBSERVATIONAL REQUIREMENTS

A minimum of one week of observations made every four hours is considered sufficient for evaluation of this application of geosynchronous satellite data. Ideally the same set of observations should be repeated at monthly intervals for three months, to assess seasonal effects during the late fall-early winter changes in thermal regime.

Three target areas would be selected to assess lithologic and geomorphic effects on the thermal expression of low level geothermal sources. Large enough areas would have to be covered so as to include regions with no geothermal source as control sites (approximately 100 km x 100 km). Such information would be used to determine how well unwanted thermal effects could be removed. Spatial resolution on the order of 0.5 km, and temperature measurements to 0.5 to 1.0°C should be sufficient for this problem.

The areas best suited for experimentation would be in the Southwestern United States, Alaska, and Western South America.

Experiments should be conducted in known geothermal areas, and SEOS results should be correlated with in-the-ground thermometer data.

6. SENSOR REQUIREMENTS

Thermal observations in the 10.5 - 12.5μm window are required, with spatial resolution on the order of 0.5 km and a sensitivity sufficient to distinguish ΔT's on the order of 1°C. Thermal is required.

7. DATA REQUIREMENTS

Imagery, thermal overlays, and computer compatible tapes, as well as ancillary temperature data gathered by a data collection platform reading out results from thermometers in the ground.

8. INTERIM ACTIVITIES

Before SEOS is launched, several SR&T projects would be desirable for laying the groundwork for latent geothermal sources exploration. Aerial thermal infrared coverage at four times a day over a period of several days is needed over a region which contains in-the-ground thermometers spaced approximately 100 meters apart. Secondly, theoretical thermal models need to be improved to the point where illumination and meteorological effects can be separated from internal heat source effects on the surface temperature. These are similar to the SR&T work desired for earthquake prediction experiments. Thermal models could be used to predict what seasons (probably winter, before snow cover), times of day (probably night-time), and frequency of observation are required for this problem. The byproducts of such an investigation are the subtle thermal patterns around known geothermal areas could be mapped, which leads to a better understanding of the three-dimensional pattern of heat flow surrounding the source, and changes in thermal patterns from producing areas could be monitored, which would improve knowledge of the effects of energy removal on the local environment, particularly ground water.

9. IMPORTANCE/JUSTIFICATION

As dwindling fossil-fuel resources become more scarce and mankind's requirements for ever-increasing energy supply continue to grow, the location of useable geothermal energy sources will become of paramount importance. The greatest benefits of such SEOS experiments may be an increased understanding of the dynamic nature of such geothermal sources. A great deal of effort has gone into the study of the dynamic nature of very obvious geothermal sources, such as volcanoes and geysers. More recently, aerial infrared surveys have been used to study changes in temperature and temperature patterns in volcanic regions (Palmason, 1970). SEOS infrared scanners should be able to improve on those results by observing these geothermal areas on a regular basis.

10. SEOS UNIQUENESS

The requirement for repeated diurnal observations for extended periods make SEOS uniquely suited to research for determining whether geothermal sources with no readily visible surface expression can be detected by infrared remote sensing.

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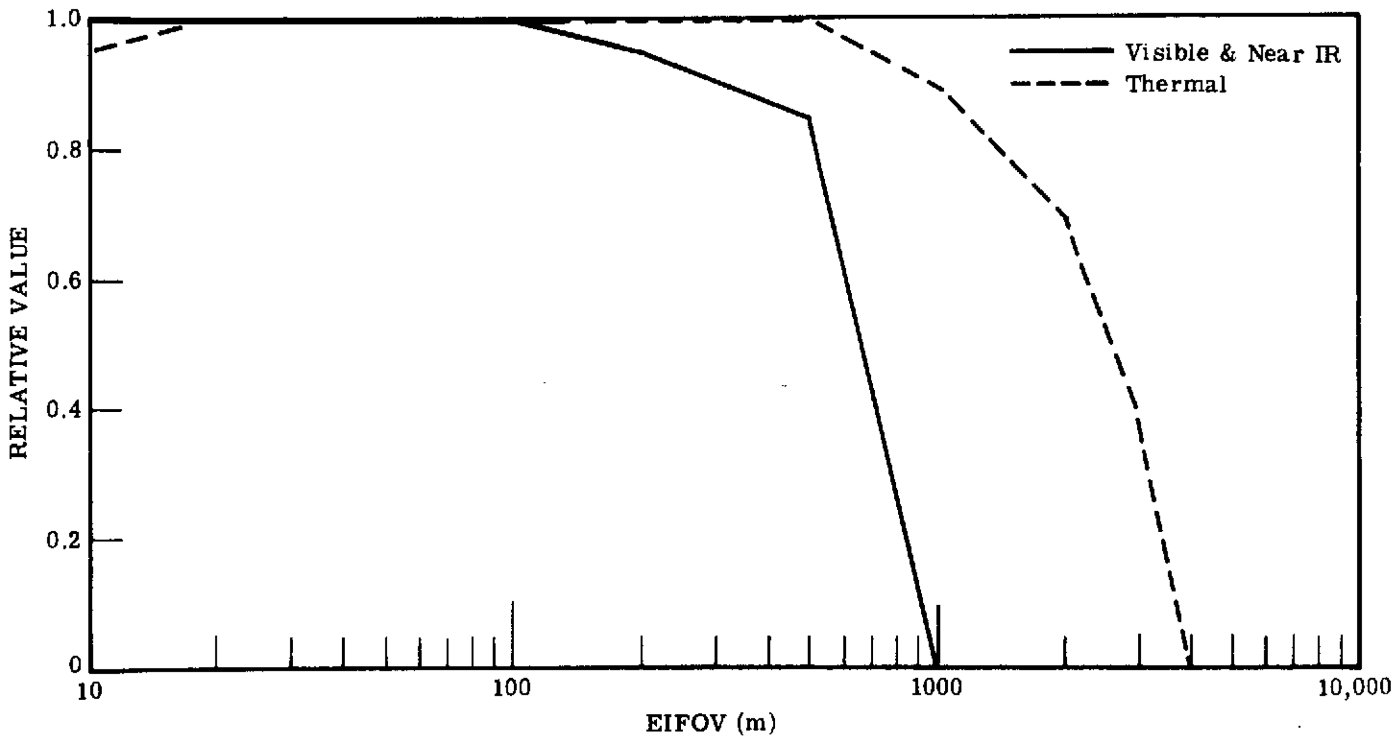
SEOS APPLICATION SUMMARY

ERIM

EXPLORATION FOR GEOTHERMAL SOURCES	APPLICATION	
U.S. Department of the Interior Atomic Energy Commission Power Companies Land Development Companies Construction Industry State Geologic Surveys	USER	
Thermal emmission; thermal inertia.	OBSERVABLE AND CHARACTERISTICS	
Late fall to early winter	Season	TIME LINE OF EVENT
3 mos. Observation window: 2 hrs.	Duration	TIME LINE OF EVENT
Three	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
Three	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
30 (5 days at 4 hr interval)	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Southwest U.S. and Western South America.	Geographic Location	SEOS OBSERVATION REQUIREMENTS
100 km x 100 km	Dimensions (m., Km.)	
Visible and NIR 120 m. nominally, thermal 500 m nominally, see attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
Broad band visible and NIR 10.5-12.5μm Thermal band is required.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
$\Delta\rho$= 1% ΔT - 0.5°C	$\Delta\rho$, ΔT (%, °C)	SENSOR REQUIREMENTS
Imagery and computer compatible tape, DCS readout of in-the-ground thermometers.	Format	DATA REQUIREMENTS
6 mos.	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Data collection platform, ground measurements of temperature, annotated maps.	Ancillary Data	DATA REQUIREMENTS
Analytical and field measurement over known geothermal source, development of accurate models (A, F, A/C).	Study	INTERIM ACTIVITIES
24 mm	Level	INTERIM ACTIVITIES
1975-1976	Time Frame	INTERIM ACTIVITIES
Field, A/C	Platform	INTERIM ACTIVITIES
Low to moderate.	IMPORTANCE/ JUSTIFICATION	
Unique due to requirement for repeated diurnal measurements over extended period.	SEOS UNIQUENESS	



APPLICATION: Exploration for Geothermal Sources

C2

MONITORING AND PREVENTION OF AEOLIAN SOIL EROSION

1. APPLICATION

The destructive effects of wind erosion are very serious. Not only is the land robbed of its richest soils, but crops are either blown away, left to die with roots exposed, or covered up by the drifting debris. Even though the blowing may not be great, the cutting and abrasive effects, especially of sand, upon tender crops is often disastrous (Buckman and Brady, 1967).

Twelve percent of the continental U. S. is somewhat affected by wind erosion, 8% moderately so, and 2-3% badly. There are two great dust bowls in the central U. S. The larger occupies much of western Kansas, Oklahoma, and Texas, extending into southeastern Colorado and eastern New Mexico. The other lies across the centers of Nebraska and the two Dakotas.

SEOS will observe soil conditions conducive to aeolian erosion and alert farmers to take preventive measures to minimize losses.

2. USERS

Agricultural Stabilization and Conservation Service
Soil Conservation Service
Farmers
Agricultural Cooperatives and Associations
Agricultural Industry

3. OBSERVABLES AND CHARACTERISTICS

Factors influencing wind erosion are soil moisture, surface condition and soil characteristics. Wet soils do not blow and wind erosion is less severe where the soil surface is rough (Campbell, 1971; Chepel, 1958).

Given the knowledge that critical soil drying had occurred and that there was a likely chance of dry weather and winds ahead, farmers could moisten the soil artifically or roughen the surface prior to onset of large scale erosion. The observable of primary importance for erosion prevention is soil moisture.

To assess the effect of control methods, i.e., irrigation, tillage, mulching, etc., and to assess the resource loss and air pollution magnitude and progress, the extent, optical density, and movement of the dust plumes could be monitored, in a regional context.

4. TIME LINE OF EVENTS/OBSERVABLES

Observations should be made during periods of hot, dry weather, in the spring, summer, or fall.

5. SEOS OBSERVATIONAL REQUIREMENTS

When weather forecasts indicate a hot, dry spell approaching and ground observations indicate soil moisture is low, monitoring of soil moisture should begin on a daily basis.

During erosion, observations of plumes should be made hourly to trace their progress and indicate their dynamic state.

The general geographic regions are the two dust bowls: 1) western Kansas, Oklahoma and Texas and southeastern Colorado, and 2) central Nebraska and the two Dakotas.

An observation format of 250 x 250 km would permit an important synoptic view of regional conditions.

6. SENSOR REQUIREMENTS

MSS	$\Delta\rho$	ΔT	Radar
.52-.56 μm	1%		1/4-2 gigahertz
.62-.68	1%		and 10 gigahertz
1-1.4	1%		
8.3-9.3		1°K	
10.5-12.5		1°K	S/N>1

Thermal bands are required.

7. DATA REQUIREMENTS

Farmers need daily information on susceptibility of their fields to erosion to allow a go/no-go decision on whether to implement protective measures. One form this would take would be thematic maps of soil moisture for the affected region.

To assess erosion, visual displays of the plumes over the period of their existence and statistics on their optical density, extent and movement are required.

Ancillary data needed are soil type maps, topo maps, and weather forecasts and data.

8. INTERIM ACTIVITIES

Basic studies are needed to learn how to relate soil burden of a plume to its optical density. Other studies need to learn more about soil moisture and characteristics and their effect on thermal ratios and ratio returns. These studies will involve ground, aircraft, and ERTS platforms.

9. IMPORTANCE/JUSTIFICATION

A major annual loss of valuable resources could be reduced while preventing crop losses as well. In addition air pollution would be abated. A conservative estimate of benefits would be \$5-10 million/year.

10. SEOS UNIQUENESS

SEOS has a unique application for these projects because of its daily and hourly observation capability.

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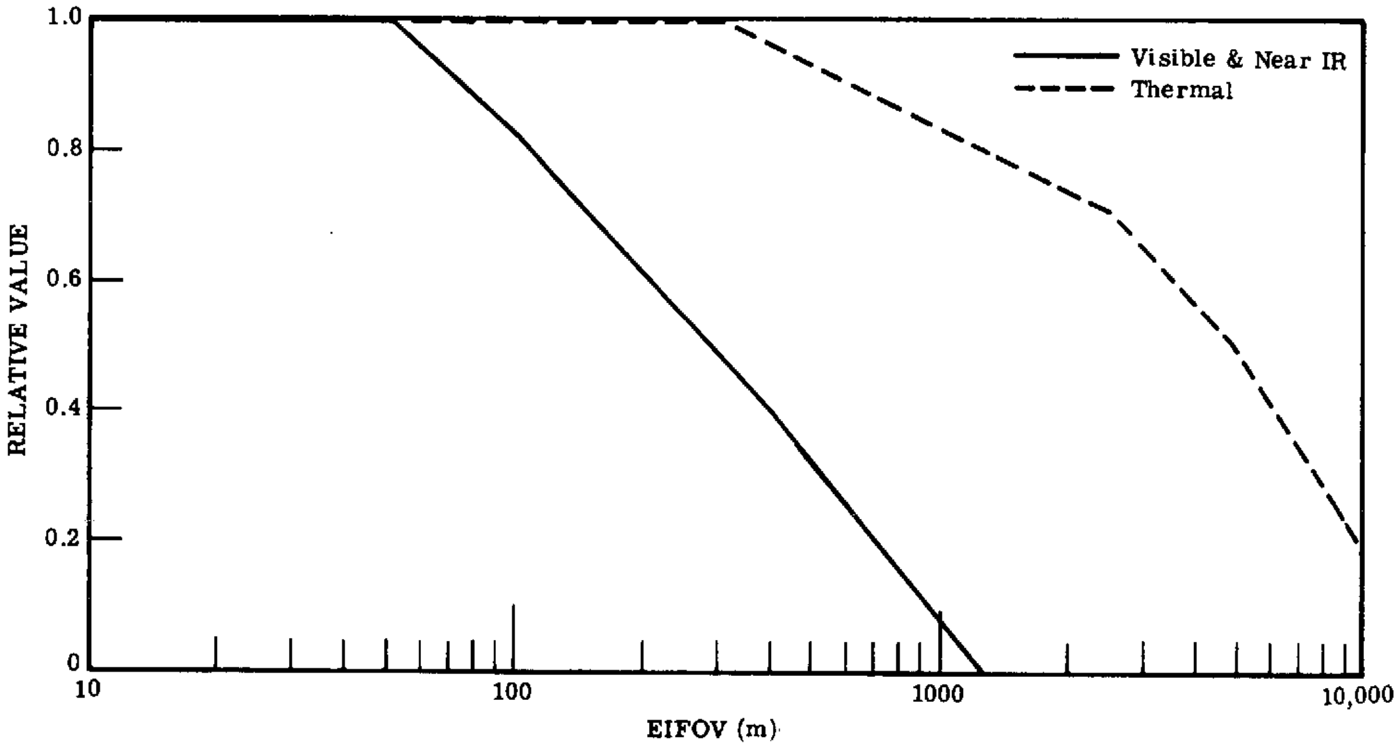
SEOS APPLICATION SUMMARY

ΣERIM

MONITORING AND PREVENTION OF AEOLIAN SOIL EROSION	APPLICATION	
USDA Agricultural Stabilization and Conservation Service Soil Conservation Service Farmers Agricultural Cooperatives and Associations Agricultural Industry	USER	
a) Soil moisture and dust plumes. b) Pixel spectra-radar returns; monitor soil moisture levels in dry periods and plume extent and optical density during active erosion.	OBSERVABLE AND CHARACTERISTICS	
Spring-Summer-Fall	Season	TIME LINE OF EVENT
6 mos,; Observation window: 1/2 hour.	Duration	TIME LINE OF EVENT
2 dependent on local climate conditions.	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
2 for prevention: daily monitoring of affected area until conditions amoliorate. In erosion assessment: during active erosion	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
1/2 hour. (∿12)	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
The dust bowls: 1) Western Kansas, Oklahoma and Texas 2) Nebraska and the two Dakotas	Geographic Location	SEOS OBSERVATION REQUIREMENTS
250 x 250 km	Dimensions (m., Km.)	
Visible and NIR nominally 50 m. Thermal and Radar nominally 300 m. See attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
MSS .52-.56 μm 8.3-9.3μm RADAR 1/4-2 gigahertz .62-.68 μm 10.5-12.5μm 10 gigahertz 1-1.4 Thermal bands are required.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
1% L°C S/N >1	Δρ, ΔT (%, °C)	SENSOR REQUIREMENTS
Imagery and computer compatible tapes. Prevention: thematic maps of soil moisture for the affected region. Erosion: plume charting and statistics on optical depth of plume.	Format	DATA REQUIREMENTS
Prevention: 12 hrs. Erosion: 2 months	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Soil type maps, topo maps, weather information	Ancillary Data	DATA REQUIREMENTS
A basic study to learn how to relate soil load of plume to optical density and to define relation of moisture to thermal ratio & radar reflection. (A, F, A/C, S/C).	Study	INTERIM ACTIVITIES
24mm	Level	INTERIM ACTIVITIES
1975-1976	Time Frame	INTERIM ACTIVITIES
Ground/A/C/ERTS	Platform	INTERIM ACTIVITIES
Less pollution, conservation of resources-$5-10 million/yr. Moderate	IMPORTANCE/ JUSTIFICATION	
Unique; due to daily or hourly observation requirements	SEOS UNIQUENESS	



APPLICATION: Monitoring and Prevention of Aeolian Soil Erosion

C3

MONITORING OF EROSION AND DEPOSITION

1. APPLICATION

The degradation of the land by shore-waves or running water produces various clastic detritus or sediment which is often transported great distances prior to its subsequent deposition. These processes, particularly such events as storm surges, rampaging streams and broad scale silting, create serious hazards in relatively short period of time. Maximum permissible time delays for data availability vary from hours to days.

2. USERS

Department of Interior
Corps of Engineers
Disaster Relief Agencies
State and Local Highway Departments
Local Public Health Offices
Coast Guard
State Land Commissions

3. OBSERVABLES AND CHARACTERISTICS

Flooded land areas
Damaged areas
Riverine sediment load
River channel changes, overflow
Coastal changes
Storm surge
Mudslides
Reservoir washouts
Broad scale inundation-silting

Radiation in visible NIR and thermal bands

4. TIME LINE OF EVENTS/OBSERVABLES

Year round capability desirable, but particularly during winter-spring. Events are measured in hour to days. Effects of events such as lowering of water levels may take weeks. Extended delays due to cloud cover would be unacceptable.

5. SEOS OBSERVATIONAL REQUIREMENTS

Observations are required along the ocean coastal regions, rarely in the major river systems. In situ sensors, historical data, and observations from aircraft should assist in predicting likely locations for sensing. "Before and after" imagery is important to be obtained whenever possible. The coincidence of rain and flooding requires taking advantage of all cloud-free opportunities in the case of such weather related phenomena.

Coverage of a 30 x 300 km area is adequate.

6. SENSOR REQUIREMENTS

0.5–0.6μm	2%	
0.6–0.7μm	2%	
0.7–0.8μm	2%	
1.0–1.2μm	2%	
10.5–12.5μm	$2^{\circ}C$	Thermal, while valuable, is not essential.

7. DATA REQUIREMENTS

Imagery
Overlays for maps
Data required on a daily basis
Weather
Tidal data
Local gauges

8. INTERIM ACTIVITIES

Study of ERTS imagery
Review cloud cover and weather data of region
Establish in situ sensor-gauges

9. JUSTIFICATION/IMPORTANCE

Highly important locally for land use assignment; immediate disaster relief to save lives, crops, livestock, property, engineering works, dams, shipping and cargoes; maintenance of river and coastal waterways and navigation aids.

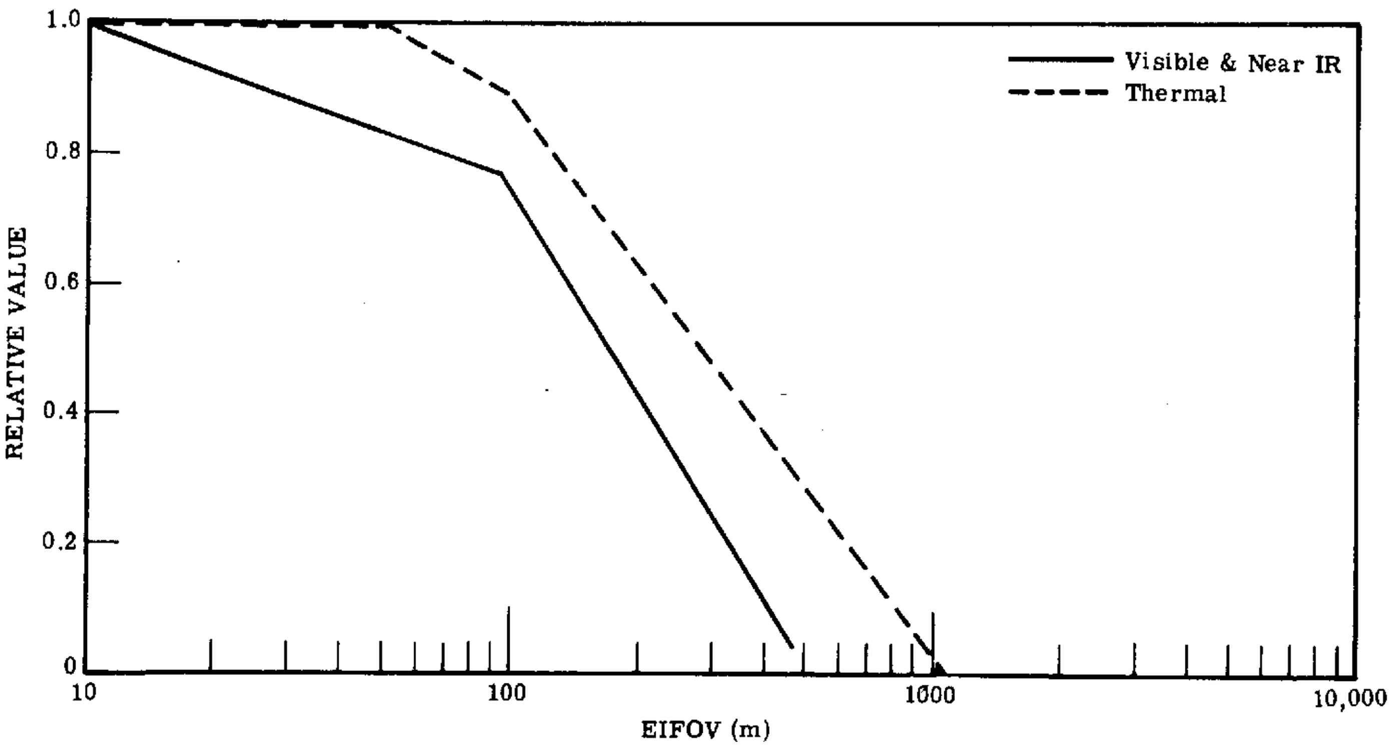
10. SEOS UNIQUENESS

SEOS is unique because of time period and multispectral synoptic viewing capability.

SEOS APPLICATION SUMMARY

ERIM

EROSION-DEPOSITION	APPLICATION	
U.S. Department of Transportation U.S. Coast Guard U.S. Army Corps of Engineers Disaster Relief Agencies Highway Departments Public Health Offices	USER	
Flooded land Damaged Areas Sediment load in streams Channel Changes Coastal Changes Reservoir Washouts	OBSERVABLE AND CHARACTERISTICS	
Year round, local flood or hurricane seasons	Season	TIME LINE OF EVENT
3 months	Duration	TIME LINE OF EVENT
3	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
1	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
10	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
ocean coasts major river valleys mountain river systems	Geographic Location	SEOS OBSERVATION REQUIREMENTS
30 x 300 km	Dimensions (m., Km.)	
100 m 200 m.	EIFOV (m.)	SENSOR REQUIREMENTS
0.6-0.7 μm 0.8-1.1 μm 2.0-2.3 μm 10.5-12.5 Thermal is valuable but not essential.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
2% 2°C	Δρ, ΔT (%, °C)	SENSOR REQUIREMENTS
Imagery, overlays, tape	Format	DATA REQUIREMENTS
1 day	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
weather hydrographic local gauges.	Ancillary Data	DATA REQUIREMENTS
signature studies	Study	INTERIM ACTIVITIES
36 mm	Level	INTERIM ACTIVITIES
1974-1975	Time Frame	INTERIM ACTIVITIES
ERTS, aircraft, and in situ	Platform	INTERIM ACTIVITIES
High local importance	IMPORTANCE/ JUSTIFICATION	
Unique because of time period.	SEOS UNIQUENESS	



APPLICATION: Erosion and Deposition

C4

MONITORING VOLCANIC REGIONS

1. APPLICATION

Prediction of volcanic eruption and mapping extent of affected area.

2. USERS

The ultimate recipient of the data are people in the affected area who must be evacuated. Government planners and disaster agencies would use the data to minimize potential disaster.

Local and Regional Planning Agencies
Local and Regional Civil Defense Agencies
U.S. Army Corp of Engineers
U.S. Department of Interior
State Police

3. OBSERVABLE CHARACTERISTICS

Much effort has gone into the study of the dynamic nature of volcanoes and their related phenomena, such as magma chambers, lava tubes, hot springs, etc. Recently, aerial infrared surveys have contributed to this research of volcanic areas by mapping changes in temperature patterns in volcanic regions (Palmason, et al., 1970). Besides their recent exploitation as inexpensive heat sources (such as in Iceland), volcanoes may yield clues as to the causes and precursors of some earthquakes. For instance, a correlation between seismic events near an island volcano and solid earth tides has been recently discovered (Mauk and Johnson, 1973). It is not unreasonable to expect that temperature changes associated with the rise and fall of magma in the chambers of a volcano (possibly correlated with earth tides or other pressure-inducing events) may be one of the useful inputs for earthquake predictions. In any case, the temperatures should be useful for predicting volcanic eruptions, which could save lives in populated areas near volcanoes.

4. TIME LINE OF EVENT

SEOS is uniquely suited to volcanology studies because surveillance could be made on a daily or twice daily basis over extended periods of time, such as six months to a year. A thermal scanner should be very useful for this purpose. Data collection platforms, tied to buried thermometers, have already been used with ERTS (EAton and Ward, 1972) and would be capable of greater frequency of observation if they were used with SEOS.

Two other features concerning volcanoes for which SEOS should be uniquely suited is surveillance of new lava flows in progress and of solid particulate aerosols thrown into the atmosphere during an eruption. Airplanes and other satellites are not always available for overflights when unexpected eruptions occur. Such capability would help save lives, even if the eruption could not be predicted, if SEOS can be called on to observe the new eruption.

5. OBSERVATIONAL REQUIREMENTS

The areas studied should be about 100 km x 100 km in dimension and should include approximately five areas on the western shores of North and South America. The ERTS and airborne experiments cited earlier should provide useful information prior to SEOS launch concerning the study of volcanoes by remote sensing methods.

6. SENSOR REQUIREMENTS

Broad band visible/near IR and thermal IR (10.5 - 12.5μm)
NEΔT $\sim$ 1°K; NE$\Delta\rho$ $\sim$ 2% Thermal band is required.
See attached chart for spatial resolution requirements.

7. DATA REQUIREMENTS

For prediction, one must monitor thermal characteristics with increasing frequency near the predicted time of an eruption. For monitoring damage and extent, one must observe during the eruption. Data must be transmitted to appropriate agency within minutes of collection.

8. INTERIM ACTIVITIES

Investigation of cause and effect relationship between eruption and temperature rise prior to eruption. Utility of low resolution thermal data in monitoring volcanic activity should progress with ERTS-B and SMS/VISSR data.

9. JUSTIFICATION AND IMPORTANCE

Geothermal energy is being considered more and more seriously as a possible answer to the growing energy crisis. Too often volcanoes only attract attention when they erupt. Thermal monitoring, leading to better understanding of the volcanic environment during quiet periods, may lend aid to those devising new ways to contain volcanic heat energy for use and may lead to prediction techniques and ultimately a saving of human lives.

10. SEOS UNIQUENESS

For observing extent of eruption, SEOS could provide the only timely source of information on the "big picture" outlook. It provides an optimum platform for daily observations over an extended period of time.

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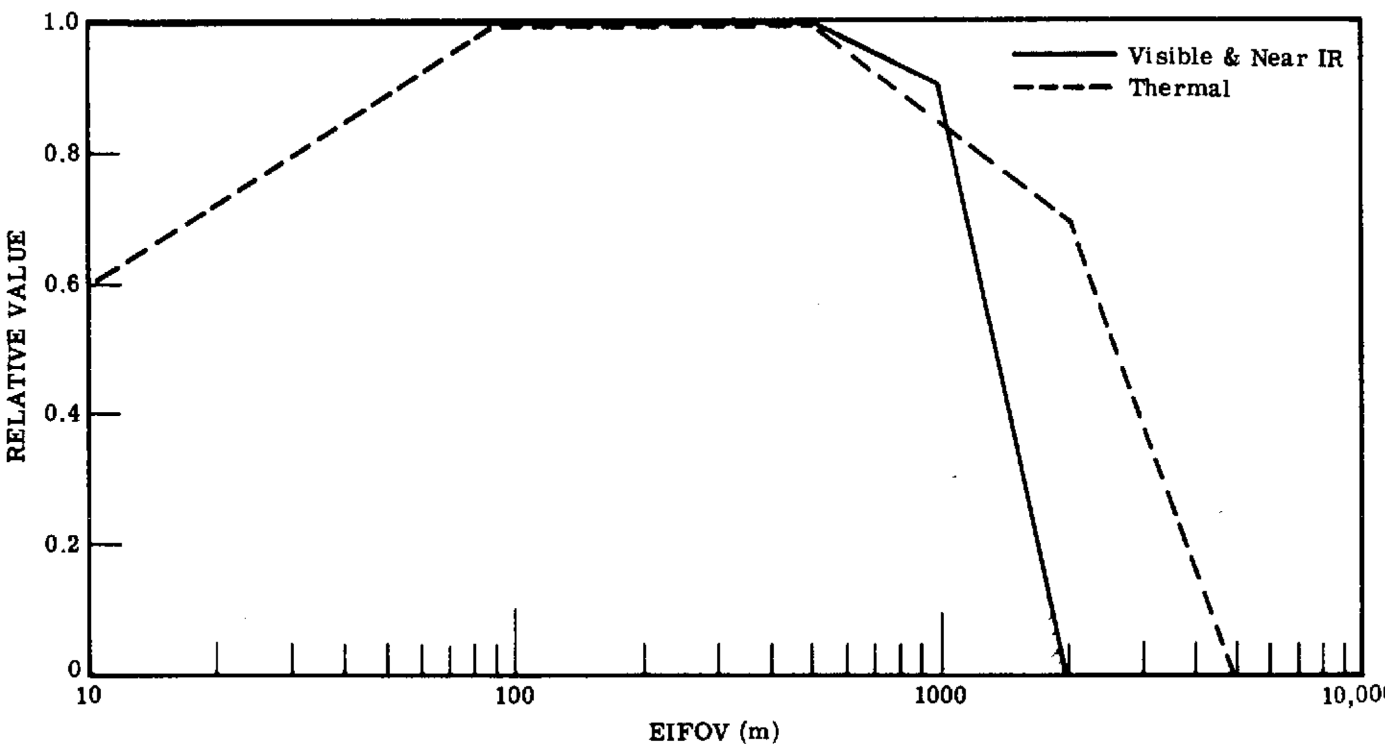
SEOS APPLICATION SUMMARY

ERIM

MONITORING VOLCANIC REGIONS	APPLICATION	
Local and regional planning agencies; State Police Local and regional civil defense agencies U.S. Army Crops of Engineers U.S. Department of Interior	USER	
Temperature, Temperature patterns Spatial and temporal changes in termpeatures of volcanic areas	OBSERVABLE AND CHARACTERISTICS	
All	Season	TIME LINE OF EVENT
6 mos. Observation window: 1 hr.	Duration	TIME LINE OF EVENT
1	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
5	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
180 (daily for 6 months)	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Western coastal regions of North and South America.	Geographic Location	SEOS OBSERVATION REQUIREMENTS
100 km x 100 km	Dimensions (m., Km.)	
500 m. nominally, See attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
Broad band visible and NIR; Thermal IR (10.5-12.5μm) Thermal band is required	Wavelength Interval (μm)	SENSOR REQUIREMENTS
2% ; 1°K	Δρ, ΔT (%, °C)	SENSOR REQUIREMENTS
Imagery and computer compatible tapes.	Format	DATA REQUIREMENTS
<1 hour	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Geographic location, winds and other related meteorological data, relayed in the ground thermometer readings via DCP.	Ancillary Data	DATA REQUIREMENTS
Analytical and field study of interrelated cause and effect relationship of temperature changes & volcanic eruptions (A,F, A/C, S/C)	Study	INTERIM ACTIVITIES
12mm	Level	INTERIM ACTIVITIES
1976-1978	Time Frame	INTERIM ACTIVITIES
A/C, ERTS-B, SMS/VISSR	Platform	INTERIM ACTIVITIES
Moderate	IMPORTANCE/ JUSTIFICATION	
Optimum, due to daily observation requirement over extended period	SEOS UNIQUENESS	



APPLICATION: Monitoring Volcanic Regions

C5

PREDICTION OF LANDSLIDES AND AVALANCHES AND MONITORING SUBSIDENCE

1. APPLICATION

Monitoring potential areas of landslides and avalanches for predictive purposes and monitoring areas of subsidence.

2. USERS

This information would be useful to all levels of government agencies and also private concerns. Examples of these users are highway departments, i.e., Colorado Department of Transportation, U.S. Geologic Survey, Army Corps of Engineers, disaster relief agencies, mining companies i.e., oil extractors in Long Beach basin, avalanche patrols at ski resorts, and construction companies.

3. OBSERVABLE AND CHARACTERISTICS

Landslides and snow avalanches are dangerous phenomena due to their sudden topographic change. These processes are often preceded by more gradual topographic changes such as slumping, a gradual movement of portions of a steeply sloping hillside. Slumping is observable as a change in the location of portions of a landform such as variations in elevation of a particular point (Terzaghi, 1950). An observation of these topographic changes by a monitoring system such as SEOS may provide early warning of avalanches and landslides.

Subsidence is a gradual lowering of a surface due to changes in the sub-soil or bedrock. These are usually areas of underground mines, extraction of liquids such as oil (e.g. the Long Beach area) or water for geothermal power plants, or limestone solution producing sinkholes. Subsidence is also observed as a variation in surface elevation (Poland, 1969).

4. TIME LINE OF EVENT/OBSERVABLE

Subsidence occurs continuously over time. Landslides can occur at any time but are predominent during periods of heavy runoff of rain, usually spring and summer. Snow avalanches are a winter phenomena.

5. SEOS OBSERVATIONAL REQUIREMENTS

Test sites for this application include: (a) two areas of potential mudslide, (e.g. a recently burned area or areas of recent construction in Southern California (Putnam, 1940), (b) two areas of possible snow avalanche (e.g. the San Juan Mts. in Colorado) and, (c) two areas of subsidence (e.g. the Long Beach oil extraction site and a karst region in Central Missouri). Monitoring of these sites should occur every three days for a 90 day period. If one of these observations indicated a sudden change in surface physiography or a potentially dangerous situation is expected, due to heavy precipitation or runoff, observations should occur every hour for as long as is necessary. A target area of 25 km x 25 km should be adequate for this application.

6. SENSOR REQUIREMENTS

Radar (of wavelengths greater than approximately 3 cm) is a potential sensor for this application which would provide an all-weather capability. Laser (or lidar) rangers are another possibility but which would not be operatable under all weather conditions (Delling, 1968). Here the main constraint would be power requirements, which are proportional to the inverse square of the range if natural targets are reflecting radiation in a diffuse manner. This would require an unrealistic amount of power (greater than a billion watts, by crude estimates). However, if corner reflectors were placed atop the suspected land or snow masses, the power requirements should be reduced to reasonable levels. These sensors are necessary to indicate gradual changes in elevation on the order of 0.3 m for the prediction of landslides or avalanches. An EIFOV up to 100 meters is optimum for these observations and an EIFOV up to 0.5 km would still be useful.

7. DATA REQUIREMENTS

Imagery and computer compatible tapes are the format needed in these applications. Data from temporal observations could be ratioed or differenced to locate areas of change. If the rate of change is considerable, more frequent observations would be initiated. Normal three-day monitoring should have a maximum data return of one day. Frequent one hour sequential monitoring must have a return of less than an hour. Ancillary data needed are knowledge of local topography and meterological forecasts.

8. INTERIM ACTIVITIES

Analytical interim activities consist of a radar and laser hardware design capable of producing useful resolutions from geosynchronous orbit. Also the placement of surface reflectors on potential target areas to increase the ranging accuracies of the sensors should be accomplished.

9. IMPORTANCE/JUSTIFICATION

With increased mining operation, liquid extractions, and numbers of people engaging in outdoor recreational activities (such as skiing), the possible dangers from landlsides, avalanches, or dramatic subsidence is increasing. A system capable of predicting these catastraphic events has the primary benefit of preventing or reducing human injury or death. The test sites chosen are only beneficial to the U. S. but the methodology developed here could be utilized throughout the world.

10. SEOS UNIQUENESS

SEOS is a very economic method of monitoring topographic change. The ability to monitor areas on demand, after intense precipitation, and at very short intervals (e.g. one hour) during periods of rapid change are unique to SEOS.

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Poland, J. F. and G. H. Davis, 1969. Land subsidence due to withdrawl of fluids, Reviews in Engineering Geology, Vol. 2, pp. 187-269.

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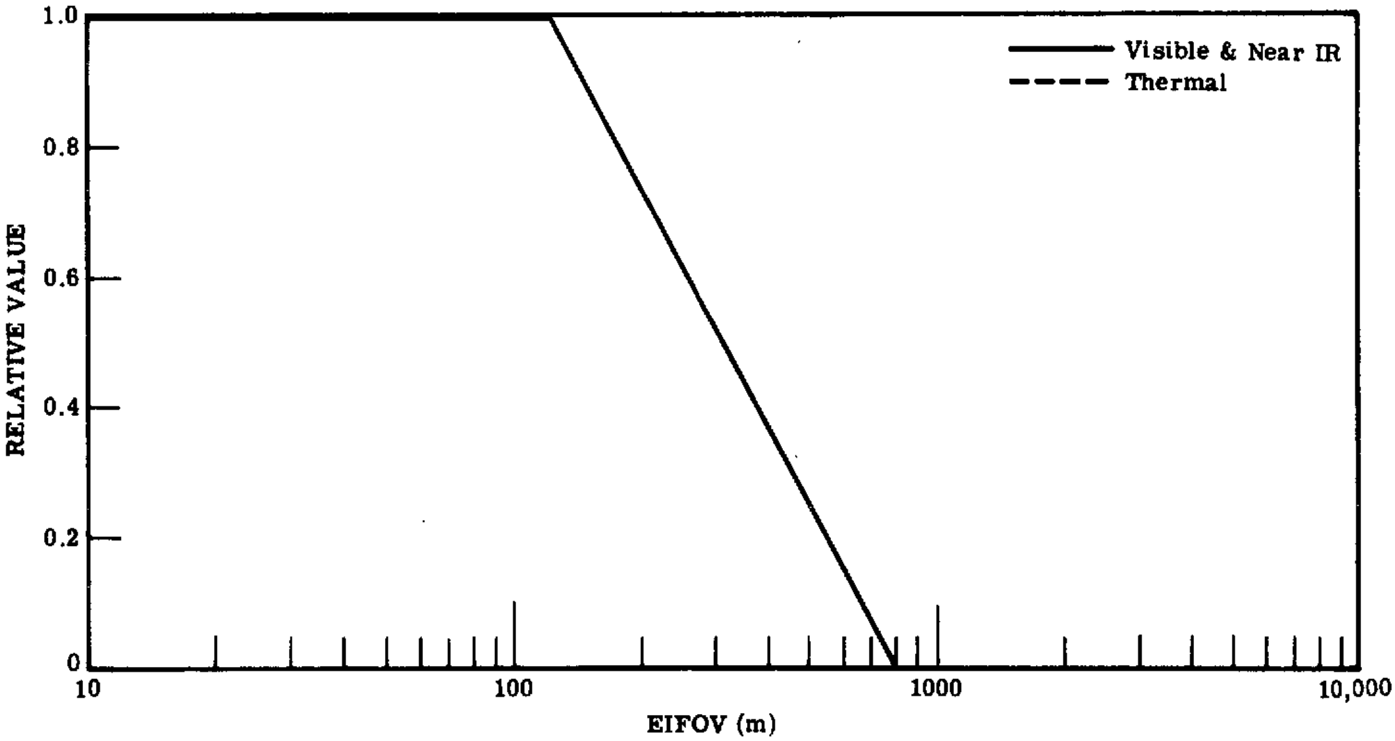
Terzaghi, K. 1950. Mechanism of landslides, Geologic Society of America, Berkey Volumne, pp. 83-123.

SEOS APPLICATION SUMMARY

ERIM

PREDICTION OF LANDSLIDES AND AVALANCHES AND MONITORING SUBSIDENCE	APPLICATION	
U.S. Geological Survey U.S. Army Corps of Engineers Highway Departments Disaster Relief Agencies Mining Companies Ski Resorts	USER	
a) Change in surface physiography i.e. elevation b) Change in ranging - radar and lidar	OBSERVABLE AND CHARACTERISTICS	
All	Season	TIME LINE OF EVENT
3 mos. Observation window: 1 hour	Duration	
3	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
2	No. Targets per Event	
42 (once every 3 days for 90 days and once per hour for 12 hrs, or as long as necessary)	No. Observ. per Target	
California, Colorado, Missouri	Geographic Location	
25 km x 25 km	Dimensions (m., Km.)	
125 m. nominally, See attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
Lidar (visible or IR); Radar (λ>3cm)	Wavelength Interval (μm)	
Height change: $\Delta h = 0.3$ m	$\Delta\rho$, ΔT (%, ^oC)	
Imagery and computer compatible tape	Format	DATA REQUIREMENTS
1 hour	Time After Observ. (Da.Wk.Mo.)	
Local topography, meteorologic forecasts	Ancillary Data	
Analytical-Radar and laser hardware design. Ground instrument development (implant reflectors)	Study	INTERIM ACTIVITIES
36 mm	Level	
1975-1978	Time Frame	
Analytical, field	Platform	
Moderate	IMPORTANCE/ JUSTIFICATION	
Unique	SEOS UNIQUENESS	



APPLICATION: Prediction of Landslides and Avalanches and Monitoring Subsidence

C6

DIURNAL AND SEASONAL VARIATIONS FOR GEOMORPHIC SURVEY

1. APPLICATION

More than 3000 conventional aerial photographs at a scale of 1:20,000 would be required to cover one ERTS-size satellite frame. Given the many areas for which base maps are either not available, inaccurate, or outdated, it is impractical to suggest that these can be made available in the foreseeable future using conventional aerial photographic techniques. Even single frames (or several frames at constant sun angle) as now available from ERTS-1, have vastly improved our ability to generate new or updated base maps for many areas. The added capability for diurnally-sequential imagery, with the inherent changes in sun-angle and goniometric reflectance effects, would even more significantly improve this ability.

As noted by the late W.T. Pecora (Pecora, 1968), high altitude photography permits a continuity of observation not possible with larger scale photographs. Relief is small compared to camera or sensor height and problems of relief displacement virtually disappear. Further, the regional significance of some geologic features is more readily recognized and interpreted in small scale photography. Even the early geomorphologists recognized that the degree of slope, roundness of features or resistence to weathering are characteristic of the materials on which these features developed.

While it is well known that some sun-angles are quite disadvantageous for photographing certain terrain conditions, given sequential observations, these same changes can be put to constructive use in landform interpretation. Variations noted in the diurnal (hence goniometric) reflectance characteristics of different terrain features, particularly in areas of sparse vegetation, can be used to selectively enhance differences in topographic development on differing geologic features.

For example, a series of critically timed observations could lead to topographic relief determination through computer implemented shadow-enhancement techniques. At very low sun angles even features with relatively small vertical relief should show contrast via imaging of their shadows. As the sun angle changes (throughout local forenoon) more of the imaged area will be directly illuminated, as shadows shorten and features of smaller relief begin to fade or wash out of the scene. Sequential imagery would show fewer and fewer details with the smallest and least severe topographic changes disappearing first in the sequence. This sequence would be repeated (in reverse order) during local afternoon changes in sun elevation, allowing for observation of both east and west slopes of selected features.

Such observations could be of significant value in generating or updating base maps, for geologic reconaissance and for mineral exploration, particularly in remote and inaccessible areas. Sequential, multi-sun-angle observation could well provide information which is unavailable in any single observation.

Fracture patterns and joints in rocks are likely to be enhanced by changes in sun-angle at the time of observation. Position and orientation of such fracture systems, as shown by alignment in topography and drainage pattern, is of direct importance in the exploration for oil, metallic minerals and water, where economically important deposits may be structurally controlled (Pecora, 1968).

The study of sand dune migration would similarly be enhanced by sequential observation. It has been suggested that such coverage could eliminate much of the time consuming mensuration associated with analysis of arid regions (Wobber, 1969). Wobber reports that Gemini photographs of White Sands National Monument contain sufficient detail to record environmental data comparable to that reported in studies by Smith (1963) or McKee (1966), but simultaneously cites the need for more frequent observation. Sequential data, collected by a geosynchronous satellite, could enhance the ability to map sand dune provenance or interdune areas, and assess topographic factors affecting sand movement or sediment depth.

2. USERS

U.S. Geological Survey

U.S. Forest Service

State Departments of Natural Resources

Highway and Transportation Departments

Mining and Exploration companies

Timber companies

3. OBSERVABLES AND CHARACTERISTICS

The key observables related to this application are diurnal sun-angle effects, such as temporal variation in illumination-shadow conditions, or unique goniometric reflectance behavior associated with specific terrain features. These may be expected to be characterized by subtle changes and minute detail interpretable only through a series of closely spaced and repetitive observations.

While, in general, geomorphological survey could benefit from observations at high spatical resolution, the capability for significantly increased temporal resolution available from geosynchronous orbit may more than outweigh losses in EIFOV. Further, this unique capability will allow geomorphological analysis and interpretation through keys and parameters otherwise unavailable.

4. TIME LINE OF EVENT

Sun angle effects of importance to this application are dependent upon both hour of day and time of year. Thus, four independent events (i.e., diurnal observations) are recommended, in order to evaluate the full range of angular effects observable at each specific latitude under investigation. Observations should be hourly, during the daylight hours, for periods of at least two days each.

5. SEOS OBSERVATION REQUIREMENTS

Requirements are for two complete daylight periods of hourly observations (under near cloud-free conditions) each season. Four targets should be investigated, covering a realistic range in topographic relief (from flat or rolling to mountainous) and in vegetation cover (from arid or barren to forested).

6. SENSOR REQUIREMENTS

As noted earlier, spatial resolution requirements may be relaxed somewhat in favor of enhanced temporal resolution available uniquely from geosynchronous orbit. Nevertheless, a 50 m. EIFOV is nominally considered as the upper limit for maximum interpretability. Beyond this resolution, fall off is rather rapid to an upper limit of 300 m., see attached graph.

Imagery in the visible and reflective IR are desirable for four test sites in the Western U.S., from the Rocky Mountains to the Pacific Coast, and from the southwest desert areas to the forests of the Pacific northwest. Each test site should be on the order of 50 km. x 150 km and positioned so as to include a maximum variation in topographic relief.

7. DATA REQUIREMENTS

Data should be provided in the form of imagery and computer compatible tapes. There is no requirement for immediate response and delays of as long as 2 months would be acceptable. Ancillary data include specific geographical coordinates and precise observation times, together with available topographic and thematic maps for test areas.

8. INTERIM ACTIVITIES

Interim activities should be aimed primarily at an analytical study of available aircraft and spacecraft data to define temporal changes in returns as related to sun angle, illumination-shadow, and goniometric reflectance function effects, for various terrain features of interest to the eventual SEOS application.

9. IMPORTANCE/JUSTIFICATION

Accurate, current base maps are extremely important in the initial exploration of an area and in the recognition of specific geologic features. Additionally, various structural parameters indicating potential oil, metallic mineral and water supplies will be analyzed through keys and interpretation techniques not otherwise available. These could lead to development and management actions of extreme importance both nationally and internationally. Such temporal interpretative keys and parameters could have very broad application in many resource areas.

10. SEOS UNIQUENESS

As implied in earlier sections, the interpretation keys and techniques to be applied to geomorphological survey in this application are not otherwise available. Thus it is unique to geosynchronous orbit, due to the requirement for critically timed observations over extended periods.

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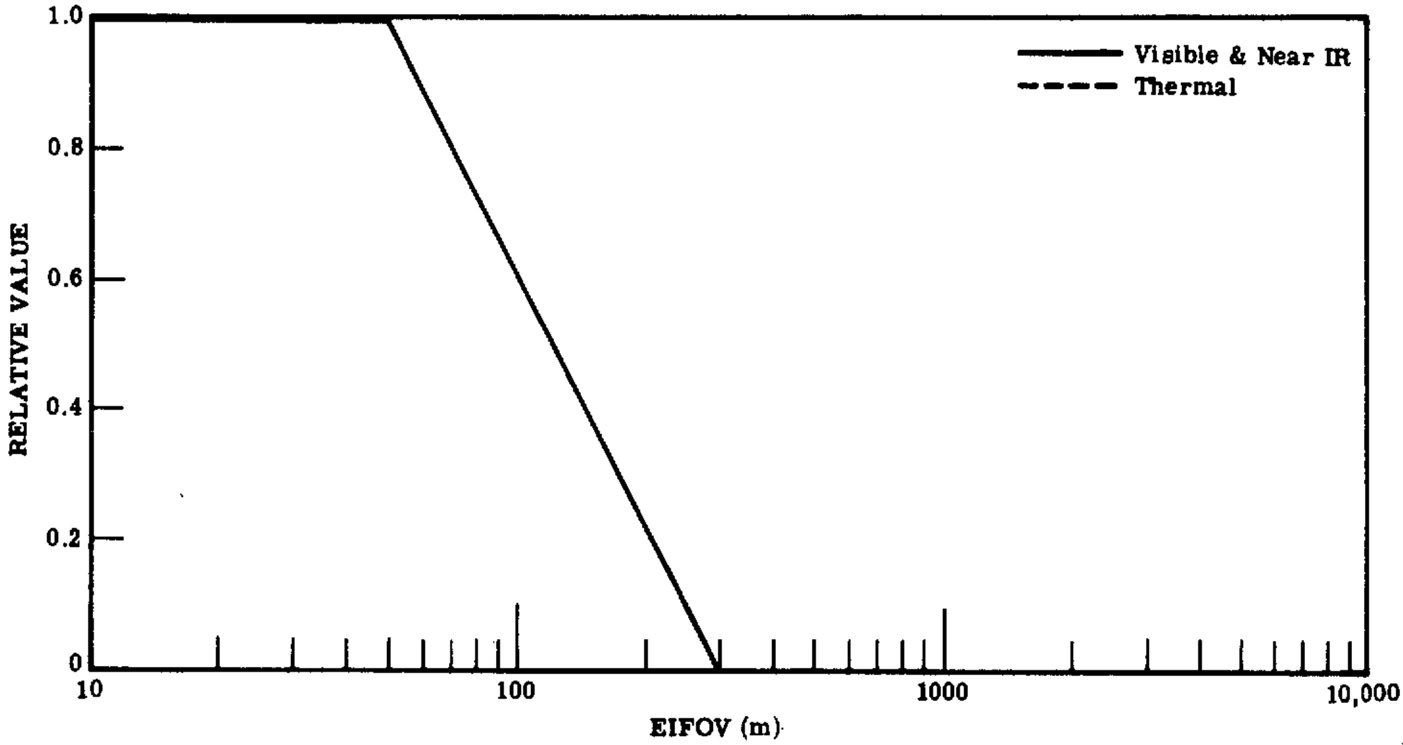
SEOS APPLICATION SUMMARY

GEOMORPHOLOGICAL SURVEY	APPLICATION	
U.S. Geological Survey, U.S. Forest Service, State Departments of Natural Resources, Highway Departments, Mining and Exploration companies. Timber companies.	USER	
Diurnal variation in illumination-shadow conditions and goniometric reflectance behavior of specific terrain features, as related to sun angle.	OBSERVABLE AND CHARACTERISTICS	
All	Season	TIME LINE OF EVENT
1 year; Observations each daylight hour for 2 days each season. Observation window: 1 hr.	Duration	TIME LINE OF EVENT
4	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
4	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
Observations each daylight hour for 2 days ($\sim$24)	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Western U.S., Rocky Mountains to Pacific Coast	Geographic Location	SEOS OBSERVATION REQUIREMENTS
50 km x 150 km each test site.	Dimensions (m., Km.)	
50 m. nominal, See attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
Multiple visible and NIR bands.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
$\Delta\rho$ = 1%	$\Delta\rho$, ΔT (%, °C)	SENSOR REQUIREMENTS
Imagery and computer compatible tapes.	Format	DATA REQUIREMENTS
2 mo.	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Geographic location, existing base & thematic maps as available, ephimeral data for sun angle determinations.	Ancillary Data	DATA REQUIREMENTS
Analytical study of existing spacecraft data to define temporal changes in returns vs. sun angle, season and terrain features (A,F,S/C)	Study	INTERIM ACTIVITIES
12 mm	Level	INTERIM ACTIVITIES
1976-1978	Time Frame	INTERIM ACTIVITIES
Apollo , ERTS-1 and ERTS-B, Skylab, etc.	Platform	INTERIM ACTIVITIES
Moderate	IMPORTANCE/ JUSTIFICATION	
Unique, due to requirement for critically timed diurnal observations.	SEOS UNIQUENESS	



APPLICATION: Geomorphological Survey

C7

DIURNAL AND SEASONAL VARIATIONS FOR LITHOLOGIC SURVEYS

1. APPLICATION

There are large regions in North and South American outside the United States which are not geologically mapped. In many of those areas, weather patterns have prevented aircraft and satellite coverage of the ground. Lithologic survey, particularly in wilderness areas, is useful for a number of reasons. First, it can help to locate new resources of previous metals and other economically valuable minerals earlier than would be expected by field geology methods. This is particularly important for resource management, on behalf of both national and industrial organizations. Even in the United States, the federal government must assess the mineral wealth of proposed new wilderness areas; sometimes this must be done on a short time scale, for political reasons. Less wealthy countries have a need to find new resources for early use, to give them the financial capital required to develop other longer-lasting industries. Second, lithologic surveys add to our understanding of the geologic history of the earth, which in turn yields clues concerning mineral deposits, earthquakes, ground water, etc. In regions where minerals have not been found, the incentive for lithologic survey is less, because such surveys are costly in the less accessible areas. SEOS can reduce these costs to an acceptable level, thereby providing more information about our planet than would otherwise be available.

2. USERS

The expected users would include the U. S. Geological Survey, U. S. Bureau of Mines, private mineral mining and exploration companies, foreign national geological surveys, and universities.

3. OBSERVABLES AND CHARACTERISTICS

ERTS data is being used to do limited lithologic surveys (Vincent, 1973a) with four channels in the 0.4-1.1μm wavelength region. Skylab will be used in a similar manner with more channels in the 0.4 - 2.5μm region, plus one broad-band 8 - 14μm channel. Aircraft data have been used to show that two medium-width infrared channels can be used to map some compositional differences among silicate rocks (Vincent and Thomson, 1972), but no satellite has been equipped with multiple thermal IR channels except Nimbus E, which operated only a short while and had a resolution of several kilometers. SEOS would be uniquely suited to observing silicate reststrahlen bands (caused by intramolecular vibrations) if it contained several thermal IR channels.

A second observable would be thermal inertia, which has been used to map lithologic units from Nimbus data (Pohn, et. al., 1972). This technique utilizes the thermal response of the earth's surface to duirnal solar illumination variations, from which thermal inertia is calculated. Though this has been applied only to surface exposures of lithologic units, it conceivably could be used to detect underground ore bodies or water reservoirs which are not obvious at the surface. The technique would really become powerful if it were used in conjunction with multiple thermal and visible-reflective IR lithologic survey techniques. For instance gossans (which can contain subsurface iron, nickel, or copper ore bodies) may have a surface stain of iron oxides and a peculiar thermal inertia, due to the weathering of sulfides out of the cavities of vesicular basic rocks.

In summary, thermal emittance, thermal inertia, and visible-reflective IR reflectance are the observables required of SEOS for lithologic surveys. Multiple thermal channels and repeated diurnal temperature measurements give SEOS unique capabilities in this application.

4. <u>TIME LINE OF EVENTS/OBSERVABLE</u>

Observations could be made in any season or in any year.

5. SEOS OBSERVATION REQUIREMENTS

There should be approximately five areas observed, on the order of 100 km x 100 km in dimension. Each area should be observed approximately four times a day for about five days.

6. SENSOR REQUIREMENTS

Three to eleven channels in the 8 - 14μm region, with spatial resolution on the order of 0.5 km or less is desirable. The visible-reflective IR channels ideally would extend from 0.4 to 2.5μm and have a resolution of approximately 0.5 km or better. Thermal bands are required.

7. DATA REQUIREMENTS

Computer compatible tapes and images are required. Data delivery time up to six months after observation would be adequate. Weather reports for all five test areas would be desirable.

8. INTERIM ACTIVITIES

Two vital theoretical studies are needed for this problem. One is the determination of optimum thermal IR channels for mapping rock types. This is now within the state-of-the-art capability (Vincent, 1973b). The other is the development of a thermal model which can predict the thermal response of lithologic units, accounting for meteorological effects. This would require improving existing models (Watson, et. al., 1972; Bornemeier, et. al., 1969; Outcalt, 1971) or combining them.

9. IMPORTANCE/JUSTIFICATION

Lithologic survey is extremely important to resource management, in guiding appropriate activities of both governmental and industrial organizations. Particularly in developing countries, optimum exploration of available resources is of great importance. In addition such surveys contribute to an understanding of geologic processes, both current and historic, and may yield information on the location of mineral deposits, ground water anomalies and earthquake prediction.

10. SEOS UNIQUENESS

This application is uniquely suited to observations from a geosynchronous satellite due to the requirement for critically timed diurnal observations over extended periods.

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Outcalt, S. 1972. The development and application of a simple digital surface-climate simulator, Journal of Applied Meteorology, 629 p.

Pohn, H. A., T. W. Offield, and K. Watson. 1972. Geologic material discrimination from Nimbus satellite data, Fourth Annual Earth Resources Program Review, Manned Spacecraft Center, Houston, Texas.

Vincent, R. K. 1973a. Ratio maps of iron ore deposits, Atlantic City district, Wyoming, ERTS Symposium, Goddard Space Flight Center.

__________. 1973b. A thermal infrared ratio imaging method for mapping compositional variations among silicate rock types, PhD thesis, The University of Michigan, Department of Geology and Mineralogy (in preparation).

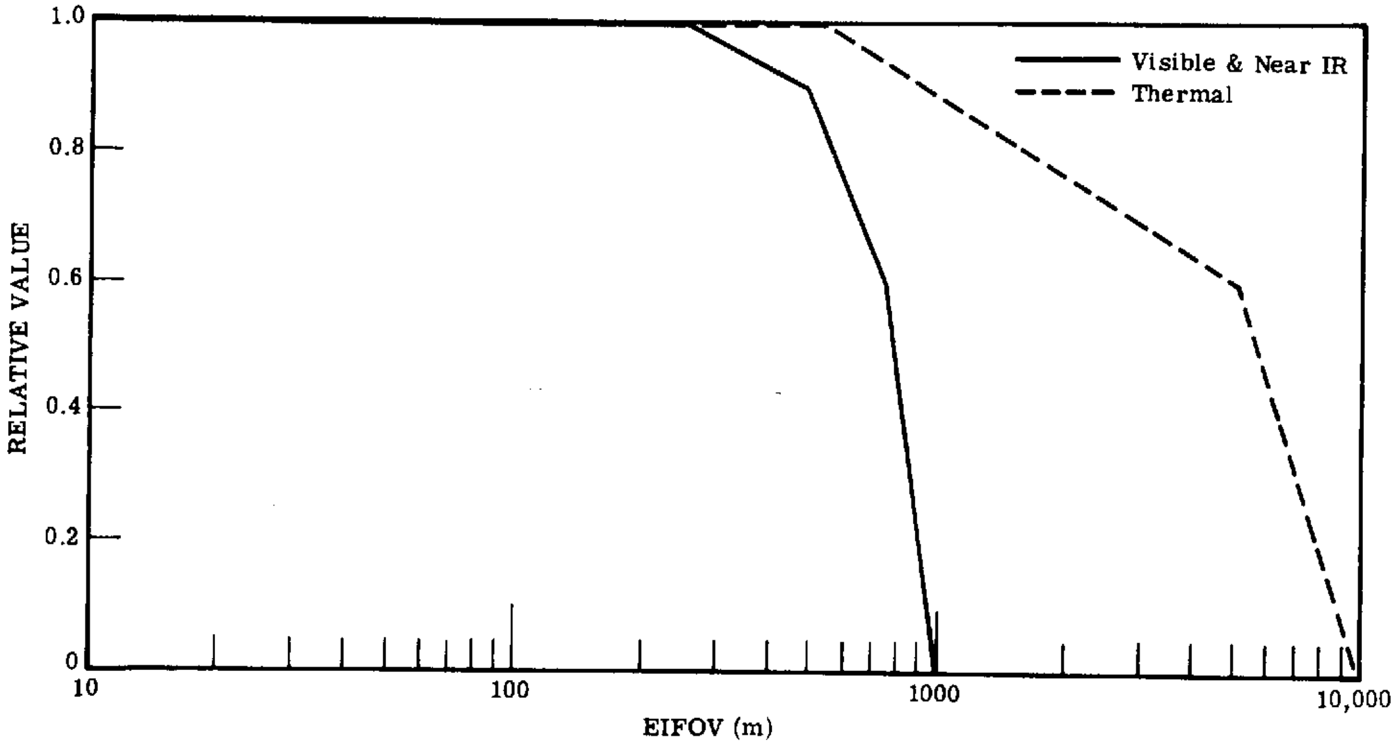
__________ and F. J. Thomson. 1972. Spectral compositional imaging of silicate rocks, J. Geophys. Res., Vol. 77, No. 14.

Watson, K., L. C. Rowan and T. W. Offield. 1971. Application of thermal modeling in the geologic interpretation of IR images, Proceedings of the 7th International Symposium on Remote Sensing of Environment, Vol. 3, pp. 2017-2041.

ΣERIM

SEOS APPLICATION SUMMARY

LITHOLOGIC SURVEYS	APPLICATION	
U.S. Geological Survey, Bureau of Mines, Foreign National Geological Surveys, The mining industry and exploration companies.	USER	
Reflectance and emission spectra characteristic of specific terrestrial materials; Thermal patterns and spatial variations in thermal inertia.	OBSERVABLE AND CHARACTERISTICS	
All	Season	TIME LINE OF EVENT
1 year. Observations at 6 hr intervals during 4 five-day periods Observation window: 2 hrs.	Duration	TIME LINE OF EVENT
4	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
5	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
Observations every 6 hours for 5 days (20)	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
	Geographic Location	SEOS OBSERVATION REQUIREMENTS
100 km x 100 km.	Dimensions (m., Km.)	
0.5 km nominally, See attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
3 to 11 channels in 3-14 μm region 8 channels in 0.4 to 2.5 μm region Thermal bands are required.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
Reflective 1%; thermal 1°C	Δρ, ΔT (%, °C)	SENSOR REQUIREMENTS
Imagery and computer compatible tapes.	Format	DATA REQUIREMENTS
6 mos.	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Weather reports, thematic maps in existence for test area.	Ancillary Data	DATA REQUIREMENTS
Analytical study to define optimum techniques and channels for discrimination and the development of a comprehensive thermal needed for interpretation purposes (A, A/C)	Study	INTERIM ACTIVITIES
24 mm	Level	INTERIM ACTIVITIES
1976-1978	Time Frame	INTERIM ACTIVITIES
Analytical, A/C	Platform	INTERIM ACTIVITIES
Moderate	IMPORTANCE/ JUSTIFICATION	
Unique due to requirement for diurnal measurements over extended periods.	SEOS UNIQUENESS	



APPLICATION: Lithologic Surveys

C8

EARTHQUAKE PREDICTION AND DAMAGE ASSESSMENT

1. APPLICATION

New breakthroughs in theoretical insight related to earthquake phenomena have been made in the past few years. As summarized by Hammond (1973), these breakthroughs may lead to the prediction of earthquakes, which are estimated to be capable of damage on the order of $20 billion in the Southern California area alone. Savings in property damage and lives can be effected by proper action, given sufficient warning time.

2. USERS

U.S. Geological Survey
State and local government agencies
Disaster relief agencies
Oil and gas companies
Local industry
Highway departments

3. OBSERVABLE AND CHARACTERISTICS

Some of the geophysical phenomena identified as precursors to earthquakes include mechanical deformation of the earth's surface, microseismic activity increases, increases in electrical conductivity of the ground, variations of the ratio of p-wave (compressional) and s-wave (shear) velocities, and changes in both chemical composition (increase in radon) and pressure of groundwater. The last three phenomena have been hypothetically related to dilatancy, whereby rocks under stress undergo a volume expansion caused by the appearance of microcracks and voids in the stressed rocks. It has been further hypothesized that ground-water diffuses into the dilated region (A. Nur, 1972 J. Whitcomb, et al., 1973).

From these observations and hypotheses, it seems possible that changes in groundwater levels may also give rise to temperature variations in a stressed region, since ground water is quite often at temperatures different from that of water, soil, or rocks at the surface. Actual observations of changes in groundwater and underground oil levels prior to earthquakes have been documented. I.G. Kissin (1970) recorded variations in water levels of wells in Russia due to stress changes at focal areas of earthquakes. H. Nunn (1925) recorded crude oil seepages through beach sands a few minutes after a magnitude = 3.6 foreshock and three hours before the main earthquake of 29 June 1925 (magnitude = 6.3) at Santa Barbara, California. The unanswered question is were there any corresponding changes in surface temperature?

There are several phenomena related to ground water level change that may be observable, besides the temperature differences between ground water and surface materials. One is the change in thermal inertia of the soil due to a higher groundwater level, i.e., the temperature response to diurnal illumination variations may be changed. Another is a variation in dielectric constant, possibly detectable by radar, caused by soil moisture changes related to varying groundwater levels

Even if earthquake prediction proves impossible from satellite, SEOS can be used to assess earthquake damage within a short time after the quake. Such information would assist decision-making by the United Nations and individual national governments concerning then immediate responses for aid to the stricken area.

4. TIME LINE OF EVENTS/OBSERVABLE

Detecting possible temperature variations prior to earthquakes would require frequent observations (possibly on the order of an hour apart) over a period of two months. The observation period is independent of season, but may be affected by the ability to see the ground surface. As for damage assessment, observations would only be required after major earthquakes in populated regions, a time line on the order of every six months. The actual observation could be made in seconds or minutes.

5. SEOS OBSERVATIONAL REQUIREMENTS

A total of 6 areas should be observed in areas prone to earthquakes in the western parts of the United States and South America. Typically, each area would have dimensions of 80 x 320 km.

6. SENSOR REQUIREMENTS

Temperature observations for earthquake prediction would require a relatively high accuracy (estimated to be on the order of $1^{o}C$ or less). Two methods of temperature detection may be possible from satellite: thermometers buried a few feet in the ground reading out to data collection platforms, and infrared radiation measurement of non-vegetated surface features, by satellite-borne scanners. Fairly gross spatial resolution, on the order of 0.5 km or less, would seem desirable for this application. For damage assessment, visible-reflective infrared data on the order of .1 km spatial resolution would be desirable. Thermal band is required.

7. DATA REQUIREMENTS

Temperature variations and visible-reflective infrared data should be presented in image form. Computer-compatible tape is also desirable for detailed analysis and correlation with other sources of data. Ground-based measurements relayed through a SEOS data collection system may also be used during the experimental program.

8. INTERIM ACTIVITIES

There are three types of SR&T research related to this problem which are recommended prior to SEOS launch. First, a field experiment is needed in an area where the Vp/Vs ratio has indicated an impending earthquake a few months hence. A network of thermometers spaced approximately 100 meters apart (or further) should be buried a few feet below the ground and monitored every hour until one or more earthquakes have occurred in the test area. Secondly, if meaningful temperature variations are detected by the thermometers, high-altitude overflights by an airplane equipped with an infrared scanner should be flown over a time period dictated by the buried thermometer experiments. Thirdly, theoretical thermal models should be developed which can account for seasonal, meteorological, and diurnal effects for specified test areas, to permit correction for these effects and prediction of the best times for observing the desired thermal phenomena.

9. IMPORTANCE/JUSTIFICATION

The idea behind this SEOS application would be to predict earthquakes on any time scale possible in remote regions, such as along an Alaskan or Canadian pipeline, or to provide warning of earthquakes in easily accessible areas, but on a shorter time scale than is now afforded by seismic or other methods. The ideal warning time would be on the order of hours to days, which would permit evacuation of people, emergency draining of pipelines, and other preparations which lead to reduced human and monetary losses from earthquakes. Even if buried thermometer, electrical conductivity, or other ground-connected observation would be a requirement for earthquake prediction, automatic data collection platforms sending continuous data back through a stationary orbit satellite would make SEOS useful for this purpose.

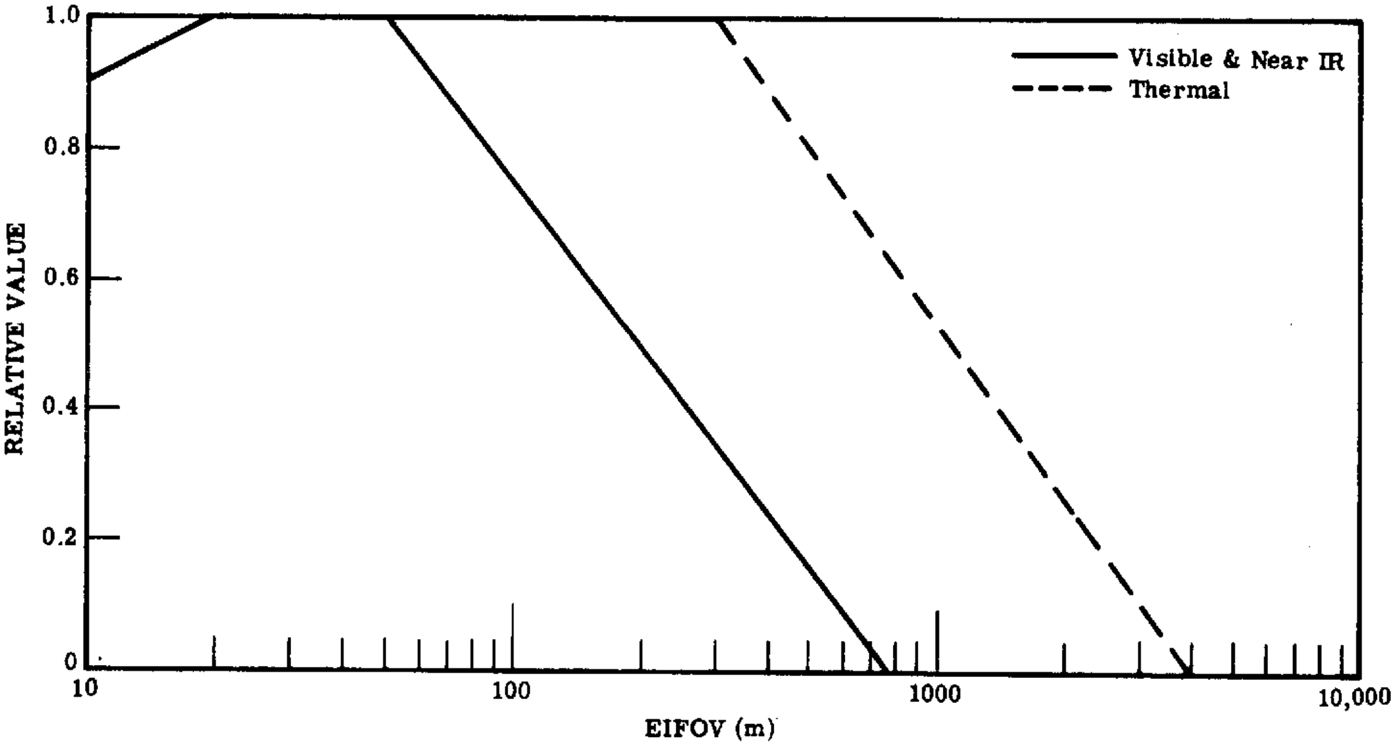
The idea behind earthquake damage assessment is that national governments and the United Nations would be able to decide at an earlier time what their aid response should be to a stricken area.

10. SEOS UNIQUENESS

SEOS capability would be unique to the extent that it could provide repetitive coverage of suspected earthquake areas at very short intervals and could be commanded on short notice to observe a quake-striken area.

SEOS APPLICATION SUMMARY

EARTHQUAKE PREDICTION	APPLICATION	
U.S. Geological Survey State and local government agencies Disaster relief agencies Local industry Oil and gas companies Highway departments United Nations; U.S. and Foreign governments	USER	
Temperature, especially diurnal variation Thermal inertia Dielectric Constant. by DCS Visible and Reflective infrared reflectnace	OBSERVABLE AND CHARACTERISTICS	
All	Season	TIME LINE OF EVENT
2 mos., Observation window: <1 hour	Duration	TIME LINE OF EVENT
1	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
6	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
Observations at two hour intervals for 30 days (360)	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Western U.S. and Western Central and South America.	Geographic Location	SEOS OBSERVATION REQUIREMENTS
30 km x 320 km	Dimensions (m., Km.)	
500 m. nominally, see attached graph (Thermal), 100 m for visible reflective IR.	EIFOV (m.)	SENSOR REQUIREMENTS
Broad band visible and NIR 10.5-12.5μm Thermal band is required.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
Δρ = 1% ΔT - 1°C	Δρ, ΔT (%, °C)	SENSOR REQUIREMENTS
Computer compatible tape and imagery	Format	DATA REQUIREMENTS
1 day routinely. <1 hour for significant changes	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Seismic readings, coordinates; DCS readout on temperature and conductivity.	Ancillary Data	DATA REQUIREMENTS
Field and A/C verification of thermal inertia effect; Analytical thermal model for seasonal and diurnal effect (A, F, A/C)	Study	INTERIM ACTIVITIES
24 mm	Level	INTERIM ACTIVITIES
1975-1980	Time Frame	INTERIM ACTIVITIES
Field/A/C	Platform	INTERIM ACTIVITIES
High	IMPORTANCE/ JUSTIFICATION	
Unique	SEOS UNIQUENESS	



APPLICATION: Earthquake Prediction

APPENDIX D

Water Resources

D1

FLOOD PREDICTION, SURVEY AND DAMAGE ASSESSMENT

1. APPLICATION

Survey of flooded rivers and shorelines will provide a record for evaluation for better flood control and minimization of economic loss to floods through land management and land use zoning. On a short-range basis, damage assessment and relief planning can be done from the imagery.

2. USERS

A wide variety of users can be identified, including agencies concerned with disaster relief, hydrologic studies, and land management. A representative list would include:

Local and Regional Planning Agencies
Local and Regional Civil Defense Agencies
State Police
State Departments of Natural Resources
Water Resources Board
U. S. A. Corps of Engineers
U. S. Department of the Interior

3. OBSERVABLES AND CHARACTERISTICS

Flood waters themselves are readily visible and should be imaged at the earliest opportunity afforded by clear or partially cloudy weather after the peak of the flood. Damaged areas from which water has receded could also be delineated. Radiation observables are in the visible, near-infrared and thermal regions.

Some thought has been given to the utility of SEOS as an early warning system for flash floods. These are generally of two types - those precipitated by spring snow melt, and those caused by heavy, localized rainfall within a confined drainage basin. The first of these is predictable, and the use of satellite information to monitor snow cover and runoff is approached in another SEOS application. The second cause of flash flooding, heavy rainfall, is a localized, unpredictable phenomenon. The occurrence of a flash flood is dependent upon the size and intensity of the storm, its location, and optimum runoff conditions. Location of a storm, and to some extent its intensity, can be measured from operational weather satellites. The volume of runoff is governed by infiltration capacities, and is related to slope, soil type and vegetation cover. It is thus directly related to the percentage of the watershed covered by impervious material, be it rock, baked earth, or urban pavement. The utility of satellites in mapping this type of information is covered in the land use applications. One possible use of SEOS for flood warning would be with a data collection system (DCS) for relaying measurements from ground-based water gaging stations, which would indicate the advance of a flood crest. This function could be carried out by a conventional synchronous communications satellite, however. The utility of SEOS for a flash flood warning system is thus minimal.

4. TIME LINE OF EVENTS/OBSERVABLE

Year-round capability is necessary but most events would be in the late winter-spring season.

Each event would last from one to several days. Following a flood crest or crests along a river basin may take up to a week.

A critical time slot is the flood peak and imaging should be done at the nearest opportunity afforded by clear or partially cloudy weather, either before or after.

5. SEOS OBSERVATIONAL REQUIREMENT

The number of occurrences and the target areas would be many each year, depending on flooding.

General coordinates are the major lake shorelines and river basins, anywhere in the U. S. or the world. Dimensions of each area would depend upon the size of the basin and the extent of flooding, but would normally be in long, linear strips, up to 30 km wide and several hundred kilometers long. In certain cases, larger area coverage may be required. The data acquisition pattern will be random and determined by observation opportunities. Imaging would be initiated on the basis of ground-based predictions of flooding events. The observation should be made at times permitted by cloud cover, beginning three to five days in advance of the predicted flood peak in a given part of the watershed and continuing past the flood peak until the waters have substantially receded. Single observations would be desirable at one day intervals, but the scheduling of sequential looks will depend primarily on cloud cover conditions. Partial cloud cover of as much as sixty percent should be accepted, but cutoff points will depend on the significance of the information in specific instances.

For specific applications demonstrations, the Mississippi River basin and the Great Lakes shorelines would be singled out. These areas are subject to periodic flooding, and good ground support and information dissemination systems would be available. In addition, several flash floods in the western U. S. would be monitored when they occur.

6. SENSOR REQUIREMENTS

EIFOV's of 100 meter would be sufficient for mapping land-water boundaries and making gross damage assessments. Detailed damage assessment would be possible only with an EIFOV of 10 meters or less.

EIFOV	λ	$\Delta\rho$;ΔT
100 m	.6 - .7 μm	2%
100 m	.8 - 1.1 μm	2%
100 m	2.0 - 2.3 μm	2%
100 m	10.5-12.5 μm	2°C

Thermal band is valuable but not essential.

The visible and near-infrared can be used to map damage areas and extent of flooding. In addition, automatic level slicing of a band around 2.0 μm can map land-water boundaries and areas of inundation (Sattinger, et al., 1973). Water saturated areas which may have been recently flooded would also be observable in the infrared and thermal bands (Hallberg, et al., 1973).

7. DATA REQUIREMENTS

Data should be provided in the form of photographic imagery and computer compatible tape. These should be delivered to the user agencies within 24 hours (Meyers, et al., 1972). The data would be used in relief planning, and to identify affected areas where more detailed coverage by ground or airborne sensors should be obtained. Automatic level slicing of a near-IR or thermal band, deliverable as transparent separations, would be useful to show the extent of flooding.

For flood plain delineation, one month would be adequate response time. Scanner data slicing and photointerpretation would be done in conjunction with river gage water level readings and ground information. This output would be used to prepare maps showing floodplain extent for future analysis and possible evaluation of damage claims.

8. INTERIM ACTIVITIES

1. Current ERTS data of coincident flooding should be examined to refine techniques of interpretation and mapping.

2. Review of cloud cover and flood duration statistics to determine effectiveness of application with respect to timeliness and reliability of acquired data.

3. Laboratory and field studies to determine signatures of land and water boundary and reliability of delineating land/water boundaries. Proportional estimation methods should be tried out for increased accuracy.

4. User contacts should be made and chains of command established for rapid dissemination and optimum use of the data.

9. IMPORTANCE/JUSTIFICATION

For damage assessment and disaster relief activities, SEOS would provide a synoptic source of information which would fill out the total flood picture based on data gathered from the ground or airborne sensors.

This would be of substantial value for major floods, such as the recent Mississippi River floods or Great Lakes shoreline flooding.

The flood plain delineation would substantially increase the accuracy of information needed for land use studies and flood control planning over present methods. Over a period of years, the body of data built up by this method would have a significant impact on the reliability of such studies.

10. SEOS UNIQUENESS

Compared to the use of airborne sensors, SEOS would have the potential advantages of synoptic coverage, operational flexibility and decreased cost. Compared to the use of a small number of ERTS satellites, SEOS would greatly increase the probability of obtaining data at critical periods.

LITERATURE CITED

Sattinger, I. J., A. N. Sellman, L. B. Istvan. 1973. Remote sensing in Michigan for land resource management. Annual Report, #193401-2-F. Environmental Research Institute of Michigan.

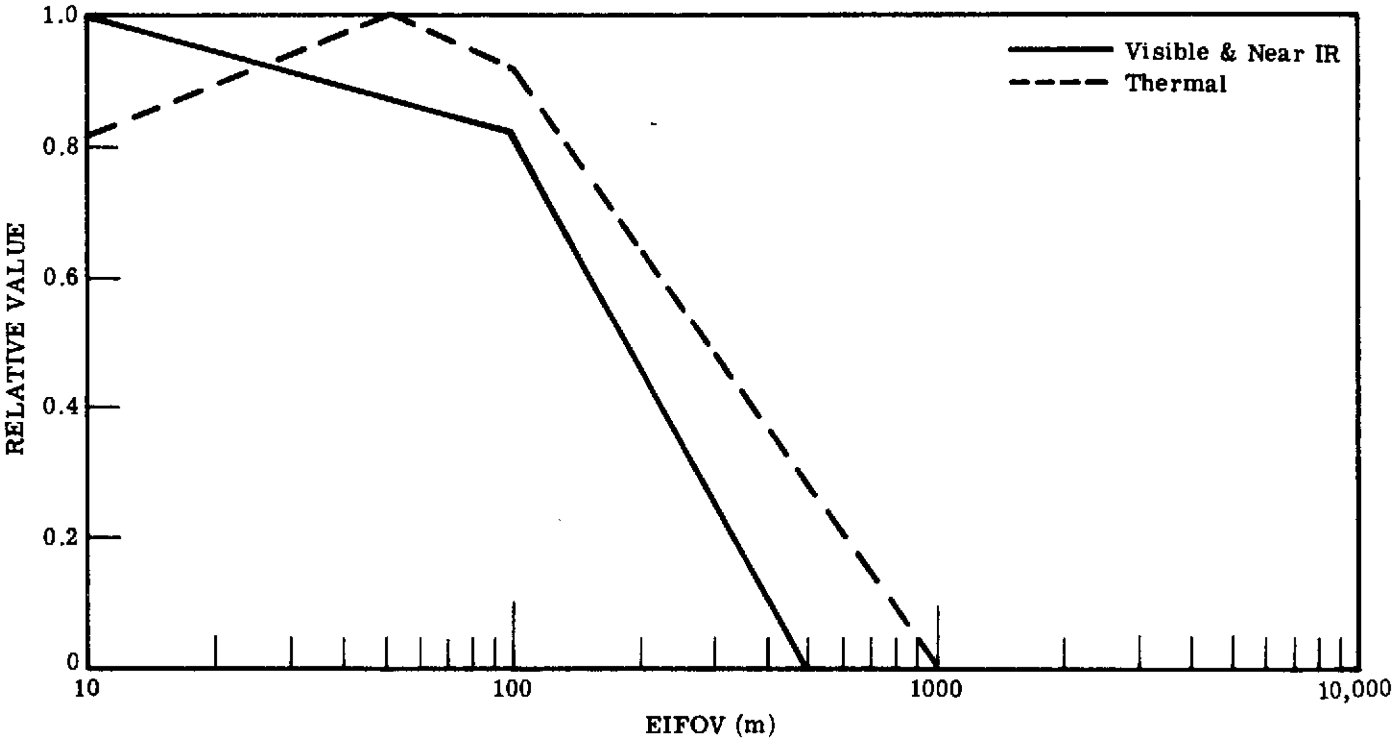
Hallberg, G. R., B. E. Hoyer, A. Rango. Application of ERTS-1 imagery to flood inundation mapping. Symposium on Significant Results Obtained from ERTS-1. NASA/GSFC, 1973.

Meyers, V. I., F. A. Waltz, J. R. Smith. Remote sensing for evaluating flood damage conditions. The Rapid City, South Dakota Flood, June 9, 1972. Remote Sensing Institute, South Dakota State University. June, 1972.

SEOS APPLICATION SUMMARY

ERIM

FLOOD SURVEY AND DAMAGE ASSESSMENT	APPLICATION	
Local and regional planning agencies, Local and regional civil defense agencies, State Police, State Departments of Natural Resources, Water Resources Board, USA Corps of Engineers, U.S. Department of Interior.	USER	
Flood waters, extent, depth, rate of change. Reflection and thermal emission patterns. Characteristic of water.	OBSERVABLE AND CHARACTERISTICS	
All, especially late winter or early spring.	Season	TIME LINE OF EVENT
3 months; Observation window: 1 day	Duration	TIME LINE OF EVENT
3	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
1	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
10	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Major lakes and rivers in U.S., Central to Southern U.S. Ohio/Mississippi Basin Great Lakes	Geographic Location	SEOS OBSERVATION REQUIREMENTS
30 x 300 km	Dimensions (m., Km.)	
Visible and NIR 10 m. nominally, thermal 50 m. nominally. See attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
0.6-0.7 μm 0.8-1.1 μm 10.5-12.5 μm 2.0-2.3 μm Thermal band is valuable but not required.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
2% 2°C	$\Delta\rho$, ΔT (%, °C)	SENSOR REQUIREMENTS
Imagery and computer compatible tape	Format	DATA REQUIREMENTS
1 day for disaster-relief activities 1 month for flood plain deliniation	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Time of observation Stream flow data Localized spot checks of water depth and extent	Ancillary Data	DATA REQUIREMENTS
Signature definition. Data Need/Dissemination survey (A, F, A/C, S/C)	Study	INTERIM ACTIVITIES
36 mm	Level	INTERIM ACTIVITIES
1974-1975	Time Frame	INTERIM ACTIVITIES
Field/A/C/ERTS	Platform	INTERIM ACTIVITIES
High	IMPORTANCE/ JUSTIFICATION	
Optimum. Due to critically tuned observations over extended periods.	SEOS UNIQUENESS	



APPLICATION: Flood Survey and Damage Assessment

D2

MONITORING EXTENT, DISTRIBUTION AND CHANGE OF SNOW COVER

1. APPLICATION

Accurate monitoring of snow accumulation and snow volume over large areas, such as the Columbia River watershed, could permit increased accuracy in both short-term and long-term predictions of streamflow. Improved accuracy of prediction would produce better allocation and control of the available water supply for power development, domestic and industrial water supply, and irrigation.

2. USERS

Improved streamflow predictions for an entire season would be helpful for all users of water resources, including agricultural production, domestic and industrial water supply, power utilities, and recreation site managers.

3. OBSERVABLE AND CHARACTERISTICS

For monitoring of snow volume, the desired information is total equivalent amount of liquid water and its distribution throughout the watershed. SEOS could contribute to this process by mapping the extent of snow cover and the rate at which this snow cover disappears during the spring thaw. Supplementary information on snow depth or snow density could be provided by spot sampling with ground survey or airborne sensor systems (Paulson, 1973), or could be inferred from the distribution of snow cover. Extent and distribution of snow cover can be provided by a single band of imagery in the visible. Thermal mapping could be used in thermal modelling to estimate snow melting rate and evaporation from reservoirs.

Techniques for using ERTS-1 data to map and measure snow area are being developed by M. F. Meier at the U. S. Geological Survey in Tacoma, Washington (Meier, 1973), and by J. C. Barnes (Barnes and Bowley, 1973). Meier has reported an ability to measure snow cover areas for a complete drainage basin with repeatability of 4% and is working on advanced methods to improve this capability. Information on snow cover area can be related to other significant variables, such as time distribution of water stored in the snowpack, energy balance over regional areas, snowline altitude, and snow depth as a function of altitude.

A study of the use of snow enhancement techniques using ERTS imagery (Wobber, et al., 1973) is primarily concerned with the use of snow cover as a means of enhancing the detection and interception of geologic features. However, the results of this work may also have applicability to the analysis of snow cover, for example, in aiding the estimation of snow thickness. Another indication of the ability to infer data from detailed analysis of snow-covered areas is given by Haefner. He reports that by using all four ERTS bands, it is possible to separate an old melting snow cover from new snow cover (Haefner, 1973). A similar observation has been made in Alaska (Weller, 1972).

4. <u>TIME LINE OF EVENT/OBSERVABLE</u>

Snow cover observations are required throughout the winter season, and preferably at two to four day intervals during the period of snowmelt in various parts of the watershed. Detailed studies (Muir, 1970) indicate that with repeated coverage at 6-hour intervals, the probability of obtaining a clear look at the snow-covered areas in the Columbia River Basin is high enough to be able to observe each major new accretion of snow during the winter months and to make adequate observations during the critical snowmelt period. SEOS would provide continuity of coverage equivalent to that assumed by Muir.

5. <u>SEOS OBSERVATIONAL REQUIREMENTS</u>

For a valid experiment, observations should be made over all or a large portion of two northern watersheds, covering an area of perhaps 10,000 sq. km. Over an entire season, a total of 90 sets of observations would be desirable, 50 of them concentrated in the spring. Spring observations should include the snowmelt season and a few continuing measurements of soil moisture content and surface temperature extending beyond the disappearance of snow. For soil moisture content measurements, a series of 4 to 8 observations must be made over a 24-hour period.

6. SENSOR REQUIREMENTS

A resolution of 200 m. is adequate for mapping snow cover over plain areas, but in mountainous areas, resolutions as good as 50 m. would give improved results. Snow cover measurements could be made in the visible, e.g., 0.6-0.7μm, and snow wetness in the near infrared. Temperature measurements should be made in the 10.5-12.5μm band. The value of $\Delta\rho$ should be 2%, and the value of ΔT should be $2^{o}C$. Thermal is required.

7. DATA REQUIREMENTS

For ease of analysis, snow cover data and surface temperature measurements should be provided in the form of both images and computer-compatible tape. Ground based measurements and aerial survey of sample areas should be used to provide supplementary information on snow depth and weather conditions. Data are needed within 48 hours of acquisition. The information on snow inventory must be introduced into extensive models of the hydrolic characteristics of the watershed, and operating procedures of the river system management process.

8. INTERIM ACTIVITIES

ERTS investigations will provide useful information on feasibility of snow cover monitoring procedures. More research is needed to fully determine feasibility of soil moisture content estimation from diurnal temperature measurements.

9. IMPORTANCE/JUSTIFICATION

A recent study (Muir, 1973) investigated the feasibility of this technique and its economic value. Appreciable benefits would accrue in the areas of increased hydropower efficiency, reduced danger of power shortage, improved flood control and warning, more efficient and reliable irrigation programs and recreation management.

10. SEOS UNIQUENESS

SEOS capability for this application is unique. Ground-based or aerial survey sampling cannot provide the extensive coverage needed for large watersheds. ERTS schedules will not provide information at critical periods during the heavy winter cloud cover or at frequent critical periods during the snowmelt season.

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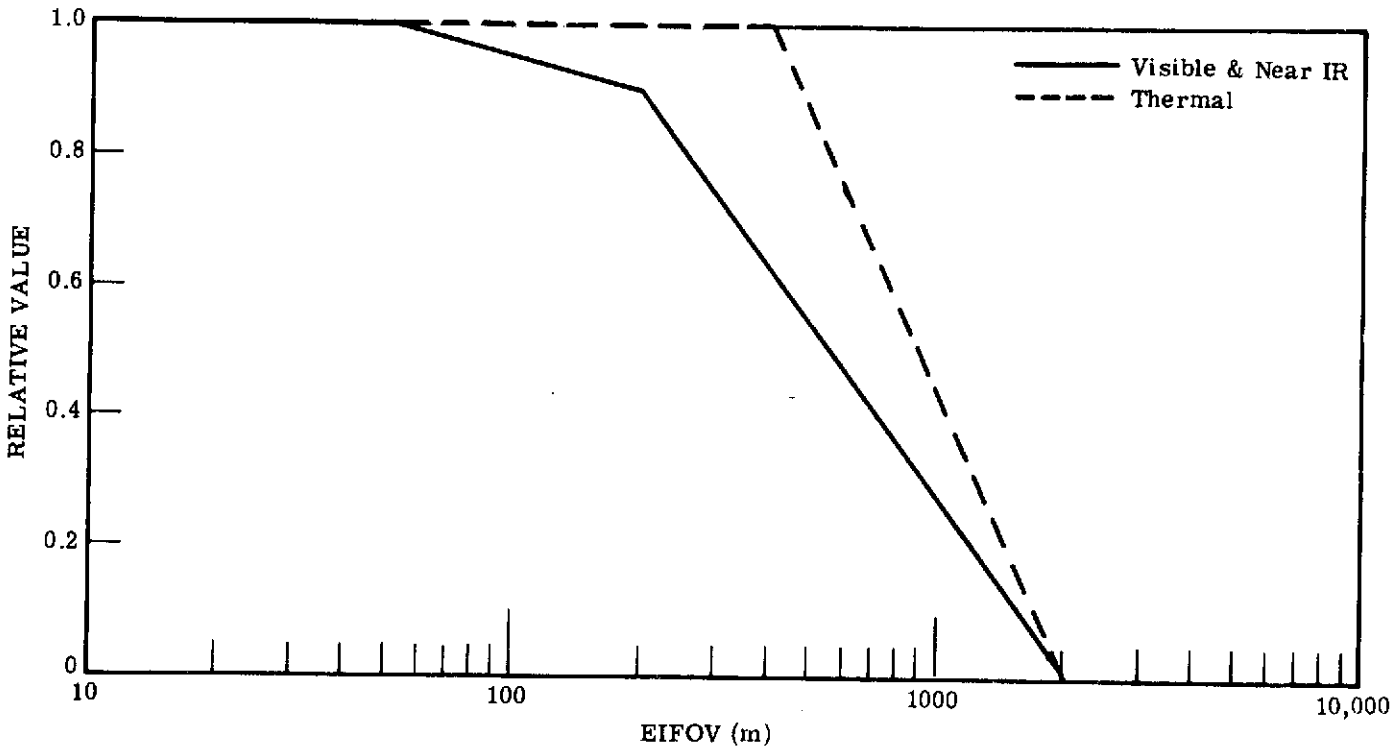
SEOS APPLICATION SUMMARY

ERIM

MONITORING EXTENT, DISTRIBUTION AND CHANGE OF SNOW COVER	APPLICATION	
U.S. Department of Agriculture Municipal water utilities Power companies Local water resource planners Recreation site managers	USER	
Extent, distribution and time rate of change of snow cover (Albedo) Soil moisture content (surface temp. variations) Reservoir evaporation (surface temp. variations)	OBSERVABLE AND CHARACTERISTICS	
Winter-Spring	Season	TIME LINE OF EVENT
3 mos. Observations at 6 hour intervals every 4th day. Observation window: 2 hours.	Duration	
1	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
2	No. Targets per Event	
Observations at six hour intervals every 4th day for 3 mos. (~90	No. Observ. per Target	
Northwest U.S.	Geographic Location	
50 km x 100 km, each site	Dimensions (m., Km.)	
Visible and NIR 50 m. nominally Thermal 400 m. nominally See attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
0.6-0.7μm 0.9-1.1μm 10.5-12.5 μm Thermal band is required.	Wavelength Interval (μm)	
5% 2°C	Δρ, ΔT (%, °C)	
Imagery and computer compatible tape.	Format	DATA REQUIREMENTS
2 days	Time After Observ. (Da.Wk.Mo.)	
Ground based spot checks: snow depth, water equivalent, soil moisture.	Ancillary Data	
Snow cover - soil moisture monit. feas. (F, A/C, S/C)	Study	INTERIM ACTIVITIES
24 mm	Level	
Winter-Spring, 1974-1975	Time Frame	
Field, A/C, ERTS	Platform	
High	IMPORTANCE/ JUSTIFICATION	
Unique due to requirement for extensive observation at critically timed intervals during periods of statistically high cloud cover.	SEOS UNIQUENESS	



APPLICATION: Monitoring Extent, Distribution and Change of Snow Cover

D3
MONITORING LAKE AND SEA ICE FOR NAVIGATION

1. APPLICATION

The monitoring of lake ice and sea ice primarily during periods of consolidation and melt to determine appropriate shipping routes and extend the navigation season.

2. Users

Any agency or governments using ships operating in ice congested latitudes could be benefited by this information. The information would be directed to controlling agencies which would then disperse the information to individual ships. The Winter Navigation Board of the Great Lakes, a multi-agency organization including representation by Federal and non-Federal public and private interests, which was organized for the specific purpose of extending navigation on the Great Lakes, would be a prime user of this information. Other agencies would be the U.S. Navy, and U.S. Coast Guard, weather bureaus at several levels, Corps of Engineers, and, on the Great Lakes, the St. Lawrence Seaway Development Corporation, Lake Carrier's Association, and Federation of the St. Lawrence River Pilots. Similar agencies from other countries would also be users of this information.

3. OBSERVABLE AND CHARACTERISTICS

Lake ice and sea ice are very dynamic physical features with the spatial location and extent of leads and polynyas of open water, brash ice, refrozen leads, and ice floes of different thicknesses changing with variations of wind, temperature, currents and other parameters. Knowledge of the location and patterns of movement or change of these features is very important for shipping, particularly in extending the navigation season. This information may be utilized to recommend favorable navigational courses for lake vessels through leads and areas of thin ice, for increased understanding of ice processes for model development for accurate forecasting of freeze-up and break-up times and movement of ice floes, and placement of devices used in the extension of the navigation season such as bubbler systems, ice booms, and optimum deployment of ice breakers. The specific ice features of open water and types of ice can be observed in a combination of certain visible and infrared bands, as thermal anomalies, or on radar imagery (Biache, 1971).

4. TIME LINE OF EVENT/OBSERVABLE

For an extension of shipping, observations should occur during periods of consolidation and break-up at the beginning and end of present shipping seasons. These periods last approximately one week and occur at different times for different locations; early December and late March for the Great Lakes.

5. SEOS OBSERVATIONAL REQUIREMENTS

SEOS observations will occur during periods of consolidation and break-up at these sites. These sites are the Straits of Mackinac, Whitefish Bay at the mouth of the St. Mary's River, and the Bering Strait. On each target/period, observations will occur once daily for a seven day period with observations at four hour intervals for one day. These time sequences would allow modelling at two different temporal scales. Target sites will encompass 100 km by 100 km areas.

6. SENSOR REQUIREMENTS

The optimum EIFOV for the detection of ice features of interest to navigation is 75 meters or less. Three hundred meters is the maximum useful resolution for this purpose. Visible and near infrared imagery of ERTS has proven useful for ice studies and could be duplicated in SEOS. The disadvantage of these sensors is their uselessness except for Composite Minimum Brightness techniques (McClain, 1971) in areas of frequent cloud cover such as portions of the Great Lakes where 90% of the days in December are either cloudy or partly cloudy. One advantage of SEOS is the ability to utilize it on the infrequent clear periods. The use of thermal imagery for ice is questionable because of the possibility of an isothermal condition during melting and confusion with cloud cover. However existing studies illustrate the usefulness of this sensor at different stages in ice development, for the detection of ice thickness, and it is useful at night - an advantage over visible band imagery (Horvath, 1971). Thus the inclusion of a thermal band of 10.5-12.5 μm with a sensitivity of $1^{o}K$ will be useful. The utility of radar in ice analysis is currently under investigation and with its virtually all weather day/night capabilities may be extremely helpful (Larrowe, 1971; Bryan, 1972; and Johnson, 1971). Thermal is required.

7. DATA REQUIREMENTS

Imagery of all sensors is the best format for ice detection. For shipping safety and navigation suggestions, imagery must be available as soon as possible with a delay of over several hours greatly diminishing its usefulness. For model building of sequential movement, formation, or melt, there is no time restraint for receipt of imagery. Ancillary data needed for ice monitoring and modeling are detailed meteorological and hydrological parameters, most of which can be obtained from existing collection agencies.

8. INTERIM ACTIVITIES

Interim activities should consist of increased research into the dynamic processes of ice formation and movement and the utility of thermal and radar sensors for ice monitoring.

9. IMPORTANCE/JUSTIFICATION

Better understanding of ice processes with subsequent modeling and the availability of recent imagery for navigation instructions in areas such as the Great Lakes and margins of the arctic and antarctic ice packs can have a significant effect to many countries. An extension of the navigation season can have military and scientific benefits and, in the Great Lakes, considerable economic benefits. Presently during spring breakup, ships must wait in harbor at a ready status until there is an assured clear channel. This costs about $3,000 per day for typical large lake vessels. Better prediction of breakup time which may be developed from SEOS obtained data would allow closer estimates of the time at which a vessel should be made ready.

10. SEOS UNIQUENESS

The monitoring of ice is presently done by different platforms and sensors and for many purposes quite effectively. However, SEOS has some capabilities which will make it a valuable addition to other sensors. Those advantages are obtaining imagery of large areas at short time intervals and the ability to obtain data basically on demand at periods of major ice changes or cloud free conditions.

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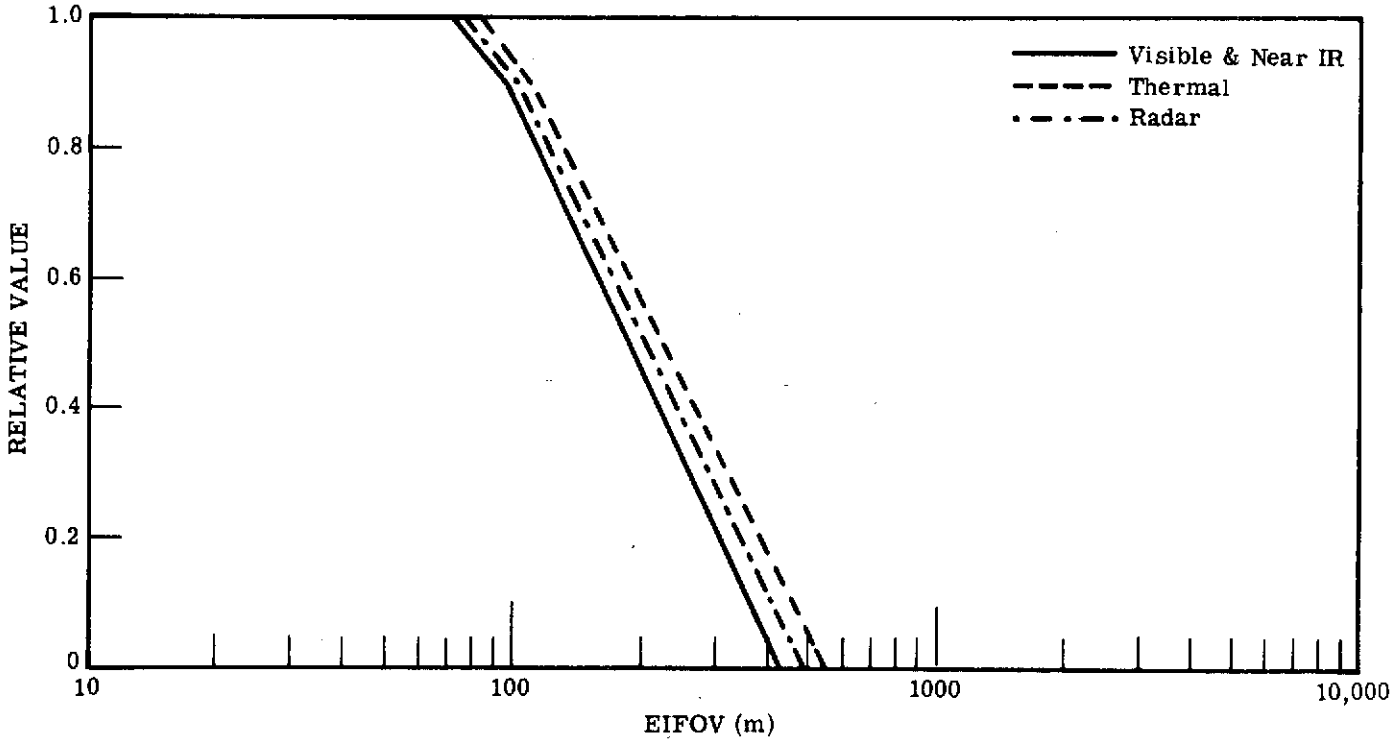
SEOS APPLICATION SUMMARY

MONITORING LAKE AND SEA ICE FOR NAVIGATION	APPLICATION	
Winter Navigation Board of the Great Lakes, U.S. Navy, U.S. Coast Guard, Weather bureaus, St. Lawrence Seaway Development Corporation, Lake Carriers Associations.	USER	
a) Open leads and polynyas, brash ice, refrozen leads, ice floes. b) Thermal differences, radar response, visible bands.	OBSERVABLE AND CHARACTERISTICS	
Freeze-up and break-up times for Great Lakes, December and March.	Season	TIME LINE OF EVENT
2 one-week intervals; 1 in Dec. and 1 in March. Obs. window 4 hrs.	Duration	TIME LINE OF EVENT
2	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
3	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
7 daily with one day at four hour intervals (12)	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Great Lakes and Bering Strait	Geographic Location	SEOS OBSERVATION REQUIREMENTS
100 km x 100 km	Dimensions (m., Km.)	
Nominally 75 m. See attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
10.5-12.5 μm Visible and near IR .4-1.1 μm Radar Thermal band is required.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
$\Delta T = 1°K$ $\Delta\rho = 3\%$ S/N - 1	$\Delta\rho$, ΔT (%, °C)	SENSOR REQUIREMENTS
Imagery and overlays of specific ice features. Computer compatible tapes.	Format	DATA REQUIREMENTS
4 hours for navigation 1 month for modelling	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Detailed hydrologic and meteorological parameters	Ancillary Data	DATA REQUIREMENTS
Utility of thermal and radar sensors for ice monitoring. Dynamic processes of ice formation and movement. (A,F,A/C, S/C)	Study	INTERIM ACTIVITIES
36 mm	Level	INTERIM ACTIVITIES
1976-1978	Time Frame	INTERIM ACTIVITIES
Ground, RB 57, other satellites (ERTS-B)	Platform	INTERIM ACTIVITIES
Medium to high for lake ice low to medium for sea ice.	IMPORTANCE/ JUSTIFICATION	
Not unique but more effective and economical than other methods.	SEOS UNIQUENESS	



APPLICATION: Monitoring Lake and Sea Ice for Navigation

D4

MONITORING AND ANALYSIS OF LAKE DYNAMICS

1. APPLICATION

Lake currents, upwellings, thermal bars, and other phenomena related to the motion of water masses within lakes are factors involved in beach erosion, unwanted pollution distribution, and coastal flooding. The measurement of these phenomena would allow steps to be taken to reduce or eliminate their adverse effects (Rouse, 1973).

Shore currents, especially along the eastern and western shore of Lake Michigan, are responsible for a marked increase in erosion of sand along beaches, and deposition of this sand at other points along the shoreline (Polcyn, 1972). The interaction of these currents with land formations could be studied by a continuous series of satellite observations over a period of a few days. Knowledge gained from these measurements will be used to design and build structures to modify current patterns and reduce damage to the shoreline caused by erosion and deposition and to place intake and discharge points for power plants and city water systems more optimally.

Lake motions and the "thermal bar" phenomenon (Noble, 1968 & Howell, 1970) also affect the distribution of pollutants, growth of algae communities, and other parameters relating to water quality. Outfall from rivers and industrial effluents are trapped near the shore, thereby increasing their concentrations and their impact on beach areas. A continuous series of satellite observations would provide information not now available to designers and managers and thus would lead to the development of measures for the alleviation of problem areas.

2. USERS

U. S. Army Corps of Engineers
Various water resources commissions
Great Lakes Basin Commission

State Departments of Natural Resources of Fishing Industry
Lake Region Landowners
Recreation Industry
Environmental Protection Agencies

3. OBSERVABLES AND CHARACTERISTICS

Observables include thermal discontinuities, visible plumes from river outflows, suspended sediments, pollutants, and perhaps artificial dye tracers. The positions and movements of these features provide information as to the magnitude and direction of currents, points of flow separation, eddy size, upwellings, and lines of water mass convergence.

Imagery in at least 4 visible channels (red, yellow, green, and blue) and one thermal channel would be needed for this application. The greater the resolution of the imagery, the more detailed knowledge can be obtained about the water movements.

4. TIME LINE OF EVENTS/OBSERVABLES

The phenomena to be investigated include 1) the thermal bar, which occurs during the spring when water temperatures are near 4°C; 2) the effects of westerly winds during the mid-summer; and 3) the shore currents set up by strong northerly winds during the fall.

Major events occur on a time-scale of 2-3 days, and could be charted by periodic observations every 6 to 8 hours. Night-time observations could be made using the thermal channel.

5. SEOS OBSERVATIONAL REQUIREMENTS

One set of observations over a 2-3 day period in the spring, summer and fall would be sufficient if conditions are favorable for occurrence of the phenomena mentioned and if system performance is adequate.

The target dimensions are 8 km x 160 km along the eastern shore of Lake Michigan or, 60 km by 100 km along the western shore of Lake Erie. The exact location and time would be ascertained by ground observations at critical locations.

6. SENSOR REQUIREMENTS

λ	$\Delta\rho$	ΔT
.42-.48 μm	1%	
.48-.52 μm	1%	
.52-.58 μm	1%	
.62-.70 μm	1%	
10.5-12.5 μm		2°C

EIFOV requirements are shown on the accompanying graph. The area of the thermal bar increases to several miles offshore as spring develops but color and temperature patterns on a much smaller scale would be required to map currents. Thermal band is required.

7. DATA REQUIREMENTS

Data are needed in the form of imagery and computer compatible tapes for each band specified. Time delay is not crucial since analysis will be performed over an extended period. Simultaneous measurements of wind speed and direction, and possible water temperatures at a few points, will be required.

Ground observations will be required to determine the optimum time and place of the satellite observations. Weather conditions, including winds and cloudiness, should be monitored for a period of a few weeks during the spring, summer and fall.

8. INTERIM ACTIVITIES

Aircraft measurements, modeling development and comparisons to current model predictions would establish feasibility of detecting associated variables.

Examination of ERTS-1 imagery for evidence of the phenomena in question would allow testing of resolution requirements and examination of atmospheric effects. If natural color and/or thermal patterns of a large enough size to be visible in ERTS imagery are not found, interim investigations into the feasibility of artificial dye tracers for measurement of currents should be undertaken.

9. IMPORTANCE/JUSTIFICATION

Coastline damage has a high economic impact. Successful measures to reduce damages, designed on the basis of these studies, could result in very considerable savings over a period of years. Concern of the State of Michigan with these problems is reflected in the passage of Public Act 245, which provides for engineering studies of shoreline erosion and for the preparation of a plan for the protection of the shoreline from such erosion.

The control of the distribution of unwanted water pollutants also has benefits for recreation, and improvement in the quality of living which cannot be easily quantified.

10. SEOS UNIQUENESS

SEOS capability is not necessarily unique, but is optimally suited to this application because the area is frequently cloudy or partly cloudy and it is necessary to take advantage of cloudless conditions when they arise. Also, continuous coverage on a diurnal cycle is needed to study the dynamics of the phenomena involved.

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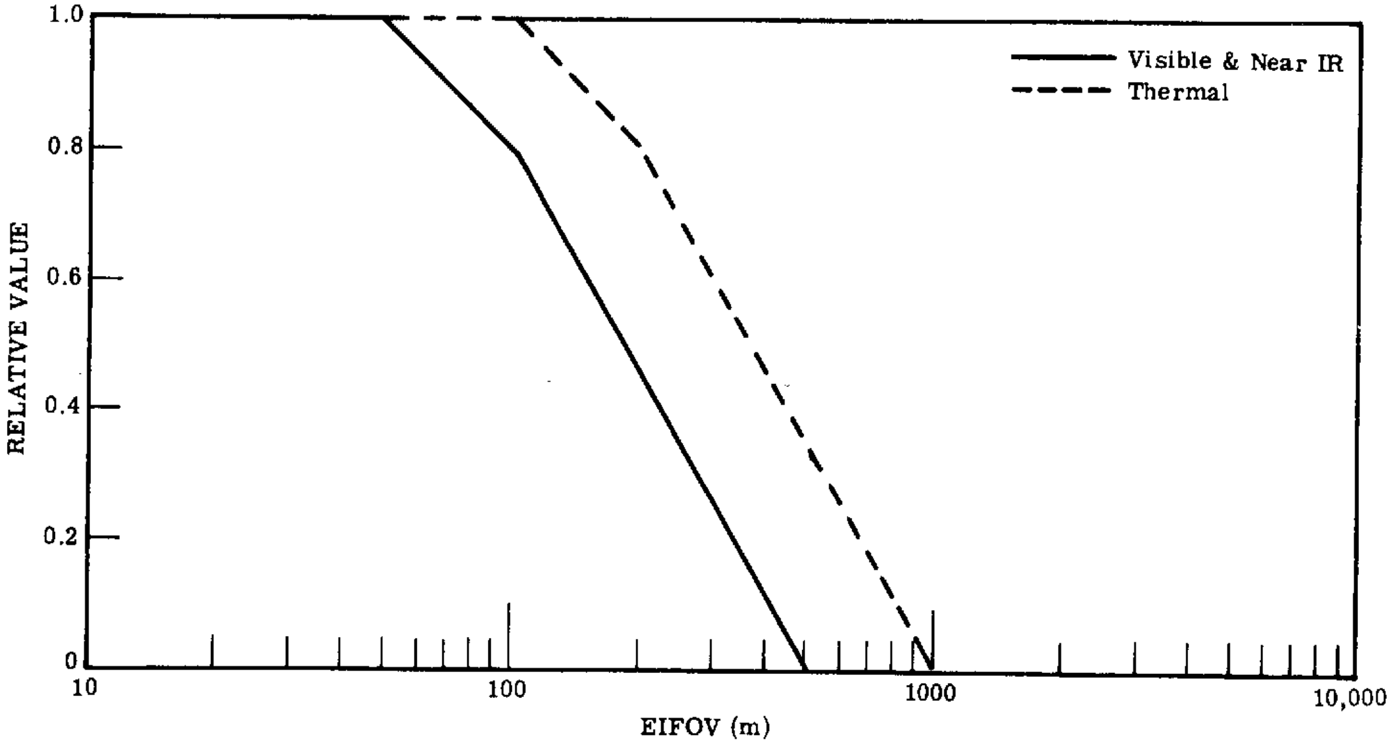
SEOS APPLICATION SUMMARY

ERIM

MONITORING AND ANALYSIS OF LAKE DYNAMICS	APPLICATION	
U.S. Army Corps of Engineers Great Lakes Basin Commission State Departments of Natural Resources Environmental Protection Agencies Various water resource commissions Fishing industry Lake region landowners and Recreation industry.	USER	
Color and temperature discontinuities identifiable in visible and thermal imagery. Position and movement of natural or artificially induced tracer targets.	OBSERVABLE AND CHARACTERISTICS	
Spring, summer, fall.	Season	TIME LINE OF EVENT
3 days each season; Observation window: 3 hours.	Duration	TIME LINE OF EVENT
6 each season (18)	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
1	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
4 (at 6 hour intervals)	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Eastern shore of Lake Michigan, Western shore of Lake Erie	Geographic Location	SEOS OBSERVATION REQUIREMENTS
8 x 160 km & 60 km x 100 km	Dimensions (m., Km.)	
20 m nominally, See attached graph	EIFOV (m.)	SENSOR REQUIREMENTS
.42-.48 μm .48-.52 μm .52-.58 μm .62-.70 μm 10.5-12.5μm Thermal band is required.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
$\Delta\rho$=1% ΔT=2°C	$\Delta\rho$, ΔT (%, °C)	SENSOR REQUIREMENTS
Imagery computer compatible tapes.	Format	DATA REQUIREMENTS
Not critical; 6 months.	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Wind speed and direction.	Ancillary Data	DATA REQUIREMENTS
Analytical study of associated parameters, establish ranges of variations of important variables (e.g. winds, cloudiness). Examine ERTS imagery for phenomena of importance to lake dynamics. (A, S/C)	Study	INTERIM ACTIVITIES
12 mm	Level	INTERIM ACTIVITIES
Spring, summer, and fall 1975-1978	Time Frame	INTERIM ACTIVITIES
Ground-based, ERTS	Platform	INTERIM ACTIVITIES
High	IMPORTANCE/ JUSTIFICATION	
Optimum	SEOS UNIQUENESS	



APPLICATION: Monitoring and Analysis of Lake Dynamics

APPENDIX E

Marine Resources and Ocean Surveys

E1
ESTUARINE DYNAMICS AND POLLUTION DISPERSAL

1. APPLICATION

Heavy sustained multiple use is a condition of most estuaries. About 40% of the industrial activity along of the United States is concentrated in the estuarine region (Council of Environmental Quality, 1970). The Bureau of Sport Fisheries and Wildlife estimates (1969) that as many as 100 million people derive significant recreational benefit from observing the wildlife in U. S. estuarine zones (Council on Environmental Quality, 1970). Estuarine areas are among the biologically most active portions of the marine environment and provide food and/or an indispensible habitat during all or portions of the life cycles of many commercially important fish and shellfish (Sweet, 1971). The complexity and variety of estuarine use is great, and also includes categories such as extraction industries, waste assimilation, land reclamation, and transporation.

Significant economic as well as aesthetic losses result from pollution. In 1969, for example, one fifth of the Nation's ten million acres of shellfish beds were closed due to contamination -- a loss of 63 million dollars (Council on Environmental Quality, 1970).

Estuaries have both economic and social importance and estuarine activities are highly interrelated due to the use of a common set of natural resources. In addition, the estuarine environment in many areas is rapidly changing due to the mounting intensity of estuarine use (Sweet, 1971). The trend toward increasing multiple-use and the resultant stress on the estuarine ecosystem may be expected to continue.

This application is concerned with obtaining, by remote sensing, the information which is necessary to effectively design and regulate -- both cost-wise and performance-wise -- waste management systems, and thereby provide for continued and better multiple use of our estuaries.

2. USERS

Bureau of Sport Fisheries and Wildlife
Bureau of Commerical Fisheries

U. S. Fish and Wildlife Service
Water Pollution Control Agencies
Environmental Quality Council
Port Authorities
Corps of Engineers
Regional Planning Agencies
Municipalities
Private Industries
U. S. Water Resources Council
Environmental Protection Agency
U. S. Bureau of Outdoor Recreation
National Marine Fisheries Service
National Coastal Pollution Research Program
National Marine Water Quality Laboratory
National Water Quality Laboratory
NOAA
National Park Service

3. OBSERVABLES AND CHARACTERISTICS

By definition, an estuary is a semi-enclosed coastal body of water which has a free connection with the open sea, and within which seawater is measurably diluted with freshwater derived from land drainage (Cameron and Pritchard, 1963). This dilution provides density gradients that produce characteristic estuarine circulation and resultant pollution dispersal patterns (NAS and NAE, 1970).

Many of the parameters necessary for the determination of estuarine circulation patterns would be detectable remotely, and because of spatial considerations, mapped more accurately than possible in ground studies. Position and movement of thermal discontinuities in relation to the main stream flow, as detected by thermal sensors, would provide such information as current direction and velocity, points of flow separation (current patterns), eddy size, upwellings, and lines of water mass covergence (i.e., thermal fronts)(Sidran and Hebard, 1972) (Strong, DeRycke, and Stumpf, 1972) (Stellar, Lewis, and Phillips, 1972)

(Mairs and Clark, 1972).

Suspended sediment (turbidity) due to storm runoff, underwater mining, dredging, and waste discharges is detectable remotely (Stellar, Lewis, and Phillips, 1972) (Nichols and Kelly, 1972) (Pirie and Stellar, 1973) (Wezernak and Roller, 1973), the optimum spectral band being a function of the type and concentration of particulate matter. In general, as suspended solids increase, the optimum band shifts from blue toward green and then red (Ross, 1972) (Mairs and Clark, 1972) (Specht, Neddler, and Fritz, 1973).

Spectral differences between saline and fresh water can be related to tidal inflow and extent of mixing (Ruggles, Jr., 1973).

Apparent water color, primarily a function of the concentration of suspended and dissolved materials (including phytoplankton, zooplankton, humus, and inorganic substances) is often an indicator of productivity, a parameter which may be influenced by introduced pollutants (Reid, 1961). This parameter is remotely detectable and may also provide information on the distribution of water masses (Polcyn, 1972).

Algal blooms (e.g., the red tide) frequently indicate the presence of certain nutrients, of biostimulation, or of certain circulatory conditions and would be detectable if sufficiently large in size in relation to the SEOS sensor capabilities (Yost, 1973).

Spectral qualities such as discontinuities in sun glitter patterns will aid in determination of current patterns (Polcyn, 1972).

4. <u>TIME LINE OF EVENT/OBSERVABLE</u>

Estuarine processes are extremely dynamic -- changing rapidly on the order of minutes and hours (Maire and Clark, 1973). The underlying influence is tidal, so observations should be undertaken with this in mind. Seasonal effects are also important.

5. <u>SEOS OBSERVATIONAL REQUIREMENTS</u>

Optimum investigation of estuary conditions would require mapping of the total target area each 2 hours for several consecutive days. Observations should be conducted daily during each season of the year.

A series of four consecutive sets of observations each season may represent a reasonable minimum upon which to base general conclusions as to dispersion dynamics with regard to a particular estuary.

Observations should be scheduled to coincide with the times of discharges of industrial or municiple wastes or of dredging or mining activities as far as possible. For sediment tracing repetitive coverage is necessary.

The dynamic condition of estuarine physics creates certain problems when considering observational requirements. Different stratification and circulation systems are produced by different ratios of river flow to tidal prism volume (NAS and NAE, 1970), a condition also influenced by topography. Dispersion of pollutants is determined largely by the mixing processes of advection and diffusion, which vary considerably according to the type of estuary (NAS and NAE, 1970).

On a geomorphological basis estuaries have been classified into four primary subdivisions (Pritchard, 1967). Within each subdivision further classification is possible based on mixing characteristics. It is suggested that a representative of each of the 4 major subdivisions be monitored and that several distinct stages along the mixing continuum be monitored for one subdivision, thereby giving a comparison of inter and intra estuarine circulation dynamics.

Possibilities are the following:

1. Drowned river valley (coastal plain estuary)
    a. Mississippi River - a slat wedge estuary; highly stratified;
    b. James River, Virginia - a partially mixed estuary;
    c. Lower Delaware Bay - a relatively homogeneous estuary.
2. Fjord estuary, such as those of Puget Sound, Washington
3. Bar-built estuary, such as Albermarle Sound, North Caroline.
4. Tectonic estuary (caused by faulting and other local conditions) such as San Francisco Bay.

It is desirable to choose experimental estuaries upon which considerable hydrologic, land use, oceanographic, pollution, and related studies have been and/or are being conducted and which are currently being heavily used for many purposes.

6. SENSOR REQUIREMENTS

Multiband data throughout the visible and near infrared and broad band thermal would be necessary. Sensitivities should be $1^{\circ}C$, and 1%. For both visible and thermal an EIFOV of 100 meters seems desirable at this time, although interim studies to better define circulation dynamics could result in relaxing this requirement somewhat. A relaxed thermal infrared resolution is acceptable particularly if high resolution reflective is available. Thermal band is valuable, but not essential.

7. DATA REQUIREMENTS

Data should be provided in the form of multispectral imagery and computer compatible tapes. To be of optimum value to the user in the area of pollution monitoring computer data should be available within 2 hours. Imagery could be available at a somewhat later time. Due to the value of a near real time capability consideration should be given to a near real time remote acquisition and preliminary processing station (portable if possible).

An extensive ground truth measurement program consisting of all pertinent meteorologic, limnologic, and hydrologic parameters should be conducted concurrently with each SEOS observation until sufficient correlations between environmental conditions and remotely sensed data have been established (Mairs and Clark, 1972). Chemical analyses of estuarine pollutants should be known along with time and rate of discharge into the estuary. In addition, accurate and current land use maps should be generated for the hydrologic basin involved. The morphology of the river channel and of the estuary basin must be known.

8. INTERIM ACTIVITIES

Study is needed in defining the EIFOV and/or spectral and thermal resolution needed for optimum detection of the various elements of estuarine circulation. In addition, study is needed to correlate environmental parameters of estuarine significance with data which is remotely collectable.

The operation of multispectral and thermal sensors in planned

ERTS-2, other satellites and/or high altitude aircraft would allow testing of resolution capabilities and atmospheric effects, and determination of optimum spectral bands and data processing techniques. In addition, high altitude overflights of the target area in a temporal scale compatible with the proposed SEOS coverage (i.e., hourly observations per day for several days) would be necessary to determine the extent of the information available as a function of time. More precise decisions could then be made as to when coverage should occur during each tidal cycle and the extent of sequential coverage necessary.

In addition, serious effort should be given to the development and refinement of models of estuarine dynamics based on remote sensing inputs (as defined by these interim studies). These should be user-oriented.

It is proposed that a 36 man month effort be undertaken throughout 1975-1978 for analytical and field study of the significant estuarine parameters.

9. IMPORTANCE/JUSTIFICATION

Many of our estuaries receive considerable polluting loads from densely populated and often heavily industrialized areas. Since the abatement and control of pollution in such circumstances invariably involves large capital expenditures, it is vital to try to ensure that monies are spent to the best advantage. Furthermore, the economic and social value of estuarine pollution control can be estimated in the millions of dollars annually (Sweet, 1971).

The knowledge of estuarine circulation dynamics and the resulting dispersal of suspended and dissolved substances that are both naturally and culturally introduced is fragmentary at best. Information provided by SEOS would make possible the effective design and regulation of municipal and industrial activities, insure the future of shelling and fishing industries, preserve wildlife and scenic amenities, and ultimately aid in obtaining maximum use of estuarine resources, not only in the United States but throughout the world.

10. SEOS UNIQUENESS

A well coordinated program capable of repeat coverages on the short temporal scale at which coastal phenomena occur is necessary in order to monitor and control the adverse effects of pollutants on this important resource (Mairs and Clark, 1972). Estuaries vary constantly in their characteristics and may change continuously from type to type as conditions alter. Coverage of the kind needed in the temporal sense could be provided by repeat high altitude aircraft flights but cost would be much greater in the long run than with SEOS and less flexibility would be available in the timing of observations.

The requirement for diurnal observation over an extended period makes geosynchronous satellites uniquely suited to this application.

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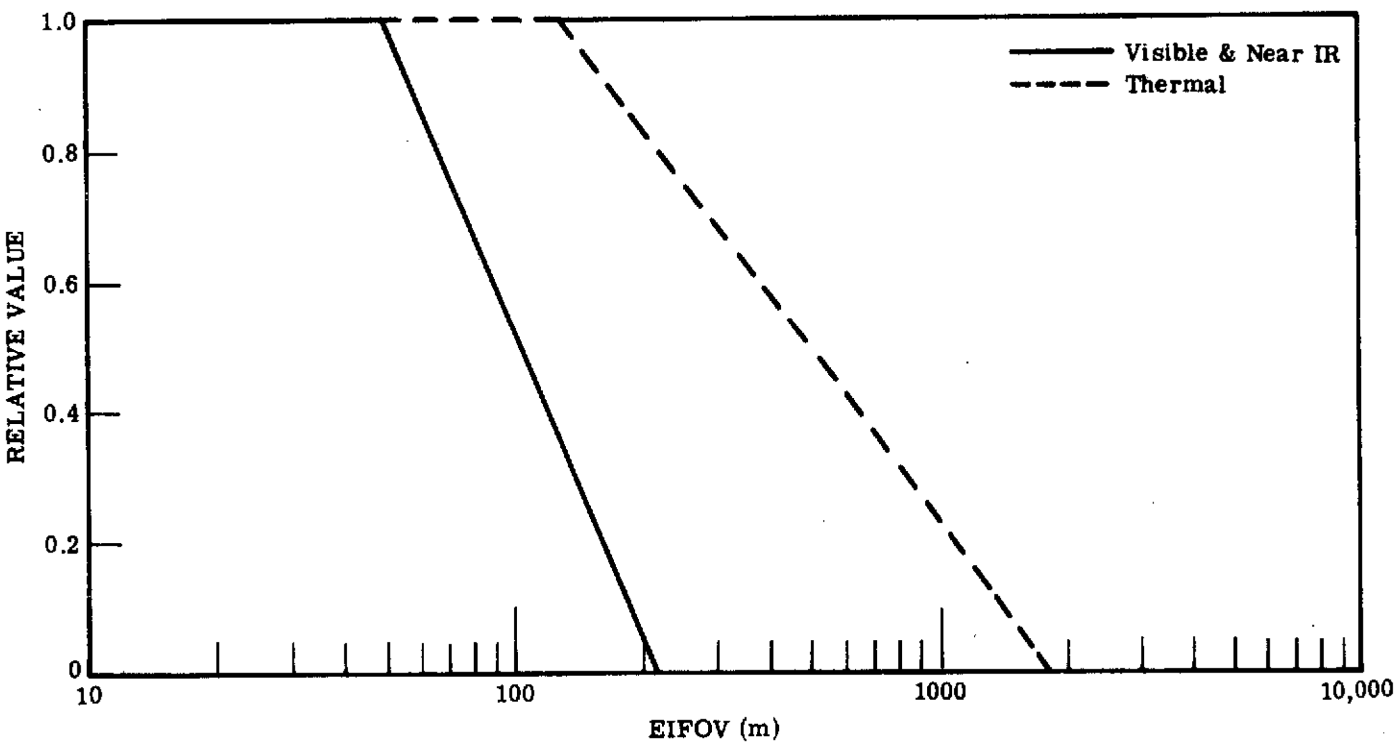
SEOS APPLICATION SUMMARY

ΣERIM

ESTUARINE DYNAMICS AND POLLUTION DISPERSAL	APPLICATION	
Bureau of Sport Fisheries & Wildlife; Bureau of Commercial Fisheries; U.S. Fish & Wildlife Service; Water pollution control agencies; Environmental Quality Council; Port authorities; Corps of Engineers; Regional planning agencies; Municipalities; Private industry, U.S. Water Resources Council; Environmental Protection Agency; U.S. Bureau of Outdoor Recreation	USER	
Thermal and turbidity patterns, color, salinity, algal blooms, spectral reflectance of environmental parameters significant in estuarine circulation.	OBSERVABLE AND CHARACTERISTICS	
All	Season	TIME LINE OF EVENT
1 year. Observations over 4 four-day intervals, seasonally correlated Observation window: 1 hour	Duration	TIME LINE OF EVENT
4	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
6	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
Observations at 2 hour intervals for four day periods. 48	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
1a. Louisiana 1b. Virginia 1c. New Jersey-Delaware 2. Washington 3. North Carolina 4. California	Geographic Location	SEOS OBSERVATION REQUIREMENTS
1a. 200 km x 50 km 1b. 150 km x 30 km 1c. 50 km x 50 km 2. 150 km x 250 km 3. 100 km x 40 km 4. 80 km x 30 km	Dimensions (m., Km.)	
50 m. nominal, See attached graph	EIFOV (m.)	SENSOR REQUIREMENTS
Five M-S bands .4-1.1 μm 10.5-12.5 μm Thermal band is valuable but not absolutely essential.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
$\Delta\rho$ = 1% ΔT = 1°C	$\Delta\rho$, ΔT (%, °C)	SENSOR REQUIREMENTS
Imagery and computer compatible tapes	Format	DATA REQUIREMENTS
2 hours (computer tapes) Imagery somewhat later	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Complete ground truth - see text.	Ancillary Data	DATA REQUIREMENTS
1. Analytical and field study of significant parameters. 2. Predictive modeling. 3. Satellite study of estuarine circulation dynamics.	Study	INTERIM ACTIVITIES
36 mm 120mm 160 mm.	Level	INTERIM ACTIVITIES
1975-1978 1975-1978 1976-1978	Time Frame	INTERIM ACTIVITIES
Field, high-altitude aircraft, ERTS, Skylab, SEASAT, geosynchronous satellite	Platform	INTERIM ACTIVITIES
High	IMPORTANCE/ JUSTIFICATION	
Unique due to cost considerations of equivalent aircraft flights and requirement for diurnal observations for extended periods.	SEOS UNIQUENESS	



APPLICATION: Estuarine Dynamics as Related to Pollution Dispersal

E2
DETECTION AND MAPPING OF SHOAL AREAS

1. APPLICATION

The need for updating navigation charts to remove doubtful hydrographic data was identified as a major problem at the Fourth Session of the International Oceanographic Committee meeting in 1965. The International Hydrographic Office has expressed concern over the status of shipping charts around the world, many of which cannot be updated due to lack of technical resources on the part of some countries. Some maps presently in use contain data based on survey records from the early 19th century, when the simplest techniques, subject to a variety of errors, were used for depth soundings (International Hydrographic Bureau, 1967).

Location information is one of the most likely sources for ambiguity on shipping charts. Positions of many doubtful shoals are known only approximately. The same shoal may have been reported with inaccurate geographical coordinates by two different ships. Storms bring rapid changes so that even recent maps may be in error due to shifting sand bars and coastline readjustments. If only surface ships are used for hydrographic surveys, a long slow process is involved and the limitations of sampling procedures affect the accuracy of the work.

Depth information on reefs, banks, continental shelves, seamounts, submarine canyons, etc., would also have other scientific or economic value in improving our knowledge of ocean areas.

A discussion with members of the Geology and Mineralogy Department of The University of Michigan (C.I. Smith, personal conversation) indicates that it would be desirable to map the contours of continental shelf areas within a range of $\pm$ 10 m. at depths of 100 m. to 200 m. and to map relief at these depths of as little as 10 m. With this capability, it would be possible to map beaches, bars, banks, dunes, etc., which were produced by ancient geological processes when water levels were much

much lower than they are now. Such mapping might provide a capability for locating and mining placer deposits of valuable minerals. Other uses of underwater topographic data might be found in connection with petroleum exploration, offshore siting of nuclear plants, etc. Various other geologic and oceanographic studies of both scientific and economic significance have also been suggested relating to analysis of tides, location of continental plates, etc. Many of these potential uses are speculative and require further analysis to determine feasibility and utility.

2. USERS.

U.S. Naval Oceanographic Office, U.S. Coast Guard
International Hydrographic Office
Commercial shipping interests, fishing industry
Mineral and petroleum exploration companies

3. OBSERVABLES AND CHARICTERISTICS

Detection of shoal areas and measurement of water depth by multispectral analysis of ERTS data are being developed by Polcyn and others (Polcyn and Rollin, 1969; Polcyn, et. al, 1970; and Brown, et. al, 1971). This technique may be good for depths of 20 to 40 m. in clear water. An alternative method in use by the Navy is based on analysis of wave trains (U.S. Naval Oceanographic Office, 1964). Wave length and direction are influenced by shoal areas whose depth is not greater than about half the wavelength.

The utility of satellite methods of locating shoal areas and determining their depth is also under investigation by Polcyn using both ERTS-1 data and EREP data. Up to the present time, major emphasis has been placed on the use of multispectral methods of depth measurement using ERTS-1 data for measurement of shallow waters less than 20 m. (Polcyn and Lyzenga, 1973). However, their use would be limited in waters with high turbidity or where bottom reflectance is variable or unknown. SEOS flexibility of observation coverage provides the opportunity to look at a shoal area when the water is clearest. Where turbidity prevents observing the bottom or shoals at depths greater than 20 to 40 m. are to be located, analysis of water wave refraction could provide data not obtainable by multispectral analysis. Extremely regular long-crested swells of 300 - 400 m. wavelength have been observed from space, for example, on Apollo 7 frame AS7-4-1607 (Polcyn and Sattinger, 1969). This frame is indicative of the type of the phenomenon which could be used to good advantage in detecting shoal areas.

4. TIME LINE OF EVENT/OBSERVABLE

Opportunities to observe regular wave patterns may occur at any season of the year, but the useful duration of the swell at a given location may amount to perhaps a day. SEOS should obtain repeated coverage of the suspected area at hourly intervals for six hours.

5. SEOS OBSERVATIONAL REQUIREMENTS

A SEOS experiment should be conducted for three or four areas in the ocean where shoals are known to exist. Shoals isolated from land areas would provide the best conditions for testing feasibility. The total areas to be observed should be 20 km x 20 km to permit adequate analysis of wave patterns. Specific test sites should be observed as opportunities arise to observe swell patterns based on ocean forecasting for known storms.

6. SENSOR REQUIREMENTS

In order to observe individual wave crests of 300 - 400 m., a resolution of 50 m. is desired, but 200 m. would still be of limited use. The spectral range for viewing is not critical, but is preferably in the range of 0.6 - 1.2 μm. A value of $\Delta\rho$ equal to 2% would be adequate.

A sensor capable of making an instantaneous exposure is preferred. If the SEOS sensor requires an appreciable time to scan and record a complete scene, this would interfere with the mapping of the true wave direction and wavelength. To deal with this problem, it would be necessary to process the resulting image to reproduce the original scene.

7. DATA REQUIREMENTS

Black-and-white photographic reproductions are satisfactory for wave analysis. Time of observation is needed as auxiliary data. Visual photointerpretation can be performed on the image, or it may be subjected to Fourier transform analysis by optical data processing methods.

8. INTERIM ACTIVITIES

Statistics on swell distribution and frequency should be analyzed to determine the number of favorable opportunities to be expected. Areas needing surveillance should be identified. Current ERTS-1 and EREP studies will provide useful experience.

9. IMPORTANCE/JUSTIFICATION

There is a considerable amount of doubtful hydrographic information on nautical charts which requires checking and confirmation. Potential benefits of improved hydrographic mapping include the following (Zissis, et. al., 1972).

- Reduction in loss of ships, cargo and lives due to shipping accidents.
- Reduction in economic loss incurred when ships are idled after involvement in a casualty.
- Reduction in environmental damage resulting from casualties resulting in oil spills.
- Reduction in the length of commercial shipping routes .
- Increased safety of submarine passage.

At depths greater than 20 m., shoals do not constitute a hazard to surface vessels, but information on these shoal areas could be useful for oceanographic or geological studies, and for mineral or petroleum exploration.

10. SEOS UNIQUENESS

Attempts to accomplish these results with airborne sensors would involve extensive flying over great distances with the need for long standby periods. Timing of ERTS observation to coincide with passage of swells from distant storms would be difficult to accomplish and would provide only a single coverage of the area. Use of ERTS to observe limited periods of clear water would also be difficult. On the other hand, SEOS could be directed at will to favorable opportunities in limited areas where shoals are suspected.

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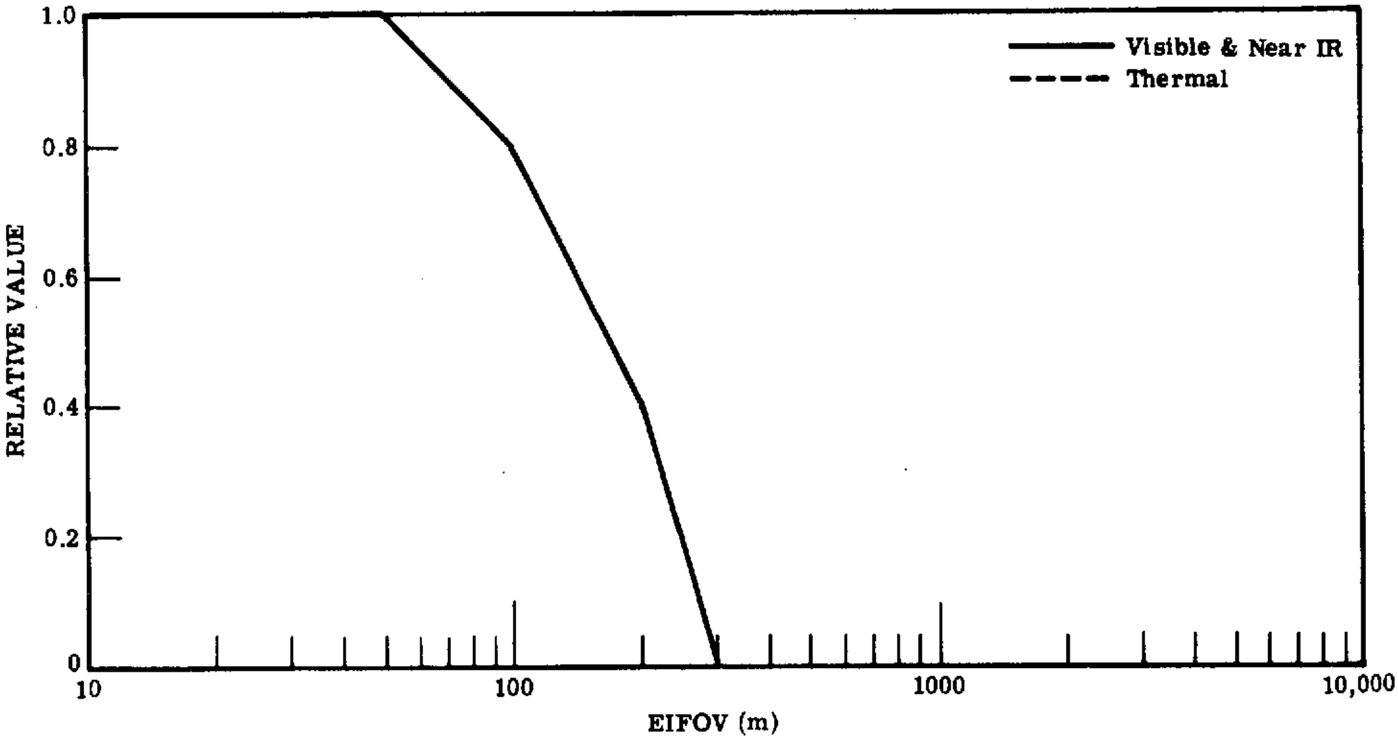
SEOS APPLICATION SUMMARY

ERIM

DETECTION AND MAPPING OF SHOAL AREAS.	APPLICATION	
U.S. Navy Oceanographic Office, U.S. Coast Guard, International Hydrographic Office, Commercial shipping interests, fishing industry, Mineral and petroleum exploration companies.	USER	
Wavelength and direction of swell initiated waves. Water wave refraction.	OBSERVABLE AND CHARACTERISTICS	
All	Season	TIME LINE OF EVENT
3 mos.; Observation window: 2 hrs.	Duration	TIME LINE OF EVENT
4	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
1	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
6 (1/hour during prime portion of event)	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Continental shelf & Atlantic Coastal area.	Geographic Location	SEOS OBSERVATION REQUIREMENTS
20 km x 20 km	Dimensions (m., Km.)	
50 m. nominally, see attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
0.6μm - 1.2μm	Wavelength Interval (μm)	SENSOR REQUIREMENTS
$\Delta\rho$ = 2%	$\Delta\rho$, ΔT (%, °C)	SENSOR REQUIREMENTS
Black and white imagery and computer compatible tape	Format	DATA REQUIREMENTS
1 mo. (not critical)	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Time of observation Geographical coordinates, wind speed, sea state	Ancillary Data	DATA REQUIREMENTS
Swell and shoal survey (A)	Study	INTERIM ACTIVITIES
12 mm	Level	INTERIM ACTIVITIES
1974-1975	Time Frame	INTERIM ACTIVITIES
Apollo, ERTS, Skylab, Open Lit. survey.	Platform	INTERIM ACTIVITIES
Moderate	IMPORTANCE/ JUSTIFICATION	
Optimum to unique due to critical timing of observation periods.	SEOS UNIQUENESS	



APPLICATION: Detection and Mapping of Shoal Areas

E3
DETECTING AND MONITORING OF THE DEVELOPMENT AND MOVEMENT OF COLORED WATER MASSES (PLANKTON)

1. APPLICATION

Monitoring the development and movements of colored water masses due to concentrations of phyto or zooplankton such as red tides.

2. USERS

Users would include federal, state, and municipal governmental agencies concerned with water quality. Examples of these are the U. S. Environmental Protection Agency, various port authorities, Federal Water Quality Administration, State Departments of Natural Resources, county health directors, and the various marine patrols. Similar agencies for other nations affected by plankton concentrations are potential users, as are various elements of the fishing industry.

3. OBSERVABLE AND CHARACTERISTICS

Red Tide is caused by a sudden population increase of the microscopic marine organism Gymnodinium brevis. When these organisms reach a certain size, they burst, die, and disintegrate producing a red or brown coloration of the water. These "blooms" often cause massive fish kills, harmful to commercial fisheries and can affect tourism and health as the dead fish drift onto beaches. The exact cause of the red tide is still unknown but is associated with excessive nutrients from surface runoff. Once started, these "blooms" can extend over many square miles of the ocean and can last several weeks. Phytoplankton and zooplankton are sometimes in such abundance, particularly in nutrient rich waters, that they present a possible health hazard. This often occurs near river outlets or bays where heavy nutrient flow is occurring. These large concentrations are observable as coloration of the water (Wezernak, 1972).

4. TIME LINE OF EVENT/OBSERVABLE

The red tide occurs randomly throughout the year and generally lasts several days to several weeks. High concentrations of plankton may be continuous features of varied intensity in a given location or may occur at random times and locations.

5. SEOS OBSERVATIONAL REQUIREMENTS

Specific observations for this application will include Tampa Bay and two "Red Tide" targets of opportunity. Tampa Bay has heavy plankton concentration due to phosphate processing along portions of its shore. SEOS monitoring of this site every 6 hrs. for two separate one-week periods could assist in understanding the origin, growth and circulation of these features. This target area should be 50 km x 50 km. The red tide targets of opportunity should be monitored every six hours and at shorter time intervals during tidal cycle for as long as necessary to assist in understanding the development and movement of these masses. Target size will vary with the bloom extent but a 100 km x 100 km area should be sufficient (Coker, 1973).

6. SENSOR REQUIREMENTS

An EIFOV of 50 meters is optimum for this purpose and an EIFOV of over 300 meters is of very limited value. The existance of plankton concentrations is indicated by a change in water color. The best sensors for this detection are visible bands (Szekielda, 1972 and Duntley, 1971). Further research may demonstrate the utility of thermal detection necessitating the inclusion of a thermal band.

7. DATA REQUIREMENTS

Imagery and computer compatible tapes useful formats for this application. If a method of control for red tides is developed, a data return on the order of 2 to 12 hours is necessary. For a system used to provide a record of data for models and scientific investigation, the rate of data return is not a prime concern. Meteorological and hydrological information from existing collection agencies and additional water sampling is needed to compliment SEOS imagery.

8. INTERIM ACTIVITIES

Continued investigation of the causes, consequences, and controls of red tides and other plankton concentrations. Also research of the usefulness of thermal channels for detection.

9. IMPORTANCE/JUSTIFICATION

Red tides and other plankton concentrations can be economically harmful to commercial fisheries and recreational industries. They can also be harmful to public health by adversely affecting water supplies. SEOS could provide a monitoring system helpful in understanding and controlling these situations and thus reduce economic and esthetic losses.

10. SEOS UNIQUENESS

The capability to provide a short term periodical synoptic coverage of an area of plankton concentration is essential to an understanding of such a dynamic situation. SEOS is perhaps the most practical and economical sensor for this application. SEOS will also have the valuable ability to monitor a target of opportunity on short notice.

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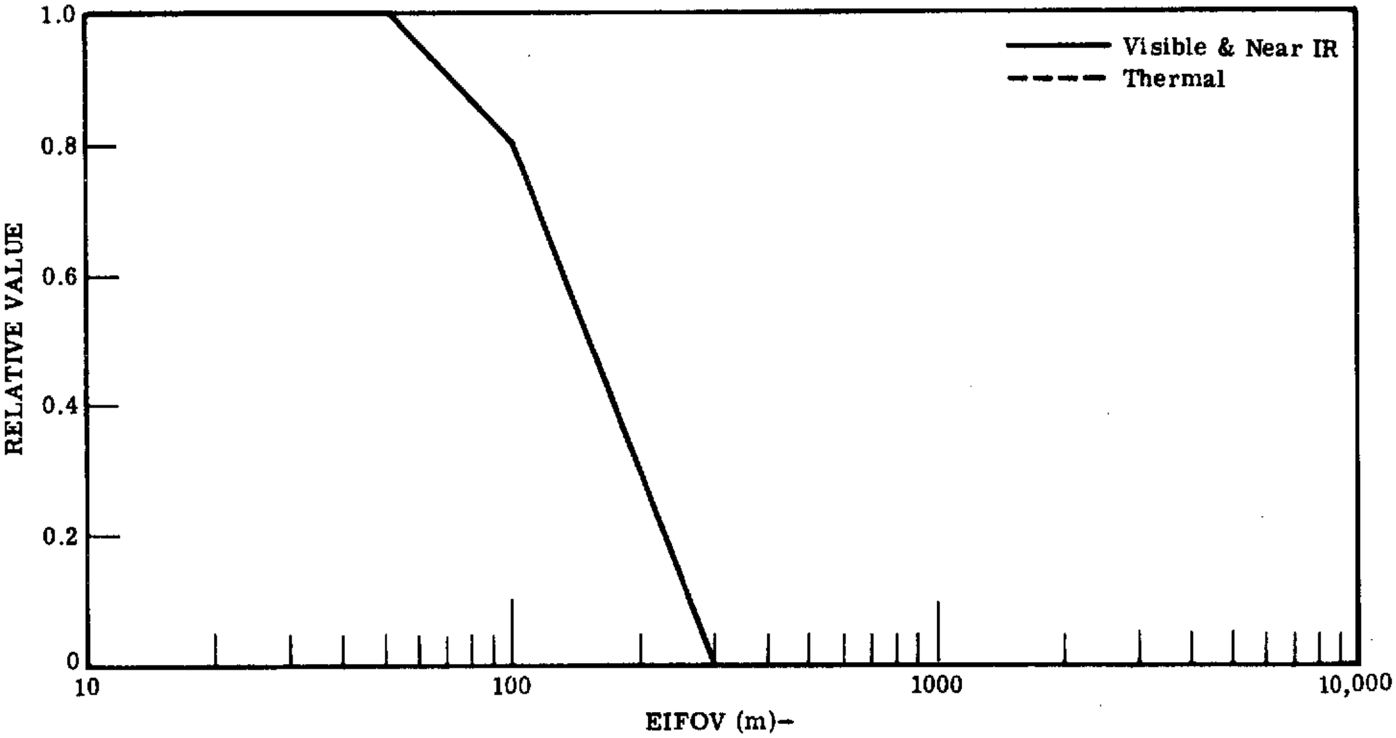
SEOS APPLICATION SUMMARY

DETECTING AND MONITORING THE DEVELOPMENT AND MOVEMENT OF COLORED WATER MASSES (PLANKTON)	APPLICATION	
EPA, Port Authorities, Federal Water Quality Administration, Health Departments, State Departments of Natural Resources, Marine Patrols, Fishing Industry, Resort Operators, Recreation Industry.	USER	
a) Plankton concentrations, red tide b) changes in spectral response in visible bands.	OBSERVABLE AND CHARACTERISTICS	
All	Season	TIME LINE OF EVENT
3 mos. observation window: 2 hours	Duration	TIME LINE OF EVENT
2	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
3	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
3 (daytime) hour intervals for one week at one hour intervals for 4 hours periods.	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Tampa Bay East and West coast of Florida–Targets of Opportunity	Geographic Location	SEOS OBSERVATION REQUIREMENTS
50 km x 50 km Tampa Bay	Dimensions (m., Km.)	
40 m nominally, see attached chart	EIFOV (m.)	SENSOR REQUIREMENTS
Visible bands .4–.7 μm	Wavelength Interval (μm)	SENSOR REQUIREMENTS
$\Delta\rho$–1%	$\Delta\rho$, ΔT (%, °C)	SENSOR REQUIREMENTS
Imagery and computer compatible tapes	Format	DATA REQUIREMENTS
for control, 2-12 hours for modelling, one week	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
meteorological and hydrologic parameters additional water samples of target area	Ancillary Data	DATA REQUIREMENTS
Analytical and field study of the causes, consequences, and controls of red tides and other plankton concentrations, (A.F. A/C. S/C)	Study	INTERIM ACTIVITIES
36 mm	Level	INTERIM ACTIVITIES
1974-1976	Time Frame	INTERIM ACTIVITIES
Ground/A/C/ERTS	Platform	INTERIM ACTIVITIES
Economic and health importance - medium	IMPORTANCE/ JUSTIFICATION	
not unique but perhaps most efficient and economical.	SEOS UNIQUENESS	



APPLICATION: Detecting and Monitoring Development and Movement of Colored Water Masses (Plankton)

E4

MONITORING AND ANALYSIS OF OCEAN DYNAMICS

1. APPLICATION

This application is concerned with the measurement and monitoring of the dynamic processes in the ocean which influence the growth of marine life, affect coastal processes, distribute pollutants, and which also influence regional weather patterns.

Contamination of the oceans by oil and other forms of pollution is now widespread, and the need of regulation is becoming apparent. Knowledge of circulation patterns in the oceans is needed to formulate regulations regarding the dumping of pollutants, and a means of monitoring the oceans for pollution is needed to enforce these regulations. The size of the areas involved and the necessity for continuous observation makes the capabilities of SEOS unique for this application. Some oceanic processes have been observed with previous satellites (Wenk, 1967) but continuous measurements are needed to study the dynamics of these processes.

Most of the world's oxygen is produced by plankton in the ocean. In addition to producing oxygen, plankton is the first link in the food chain of the sea, and is therefore important to the fishing industry. The plankton population is controlled by nutrients supplied by upwellings in the ocean, and may be threatened by pollution. Both of these factors depend upon circulation phenomena which could be monitored by SEOS. According to Yotko (1972), satellite monitoring of plankton production "could be considered equivalent to a gauge providing information on life support systems aboard spacecraft." This should therefore be considered as a prime application of SEOS.

A great deal of damage is done annually to coastal areas by erosion, storms, and tidal waves. Some of this damage could be eliminated if an observation and monitoring program were established, early warning were given or if new types of shore structures were built. Satellites have already been used to measure currents using Tiros (Cameron, 1965) and ERTS (Maul, 1973) imagery. However, continuous observation is needed to study the dynamics of these phenomena, and a monitoring capability is required to provide warning for sudden, destructive events such as storms and tidal waves. These could be provided uniquely and optimally by SEOS.

Finally, ocean currents have an important influence on the climate (e.g., the link between the Gulf Stream and the weather in the wine-producing provinces of France). Closer observation of ocean circulation patterns using SEOS may therefore have important economic and social benefits due to this connection.

2. USERS

Many organizations require oceanographic information. Among them are:

NOAA
EPA
U. S. Navy
U. S. Department of Transportation
U. S. Department of Interior
U. S. Army Corps of Engineers
U. S. Coast Guard
United Nations
International Oceanographic Commission
FAO

3. OBSERVABLES AND CHARACTERISTICS

Plankton populations, pollutants, and suspended sediments appear as color differences which can be obtained by viewing the ocean surface in several visible channels (Ewing, 1969). Upwelling and currents appear as thermal discontinuities which can be observed using an infrared channel. The magnitude and direction of currents can be measured by observing the change in the position of these color and temperature patterns over a period of time. Sea state, sun glitter, and inferences from cloud patterns can also be used for monitoring important processes.

4. TIME LINE OF EVENTS/OBSERVABLES

Transitional and stable seasonal samples should be obtained. Six seasonal periods such as winter, early and late spring, early and late summer, and fall should be monitored. Three observations per day lasting over two-week periods would be desirable. Timing of phenomena would be a function of geographical location.

Correlation of surface patterns with meteorological conditions can also affect timing requirements. For example, a study of the interaction of hurricanes with ocean currents would require more frequent sampling.

5. SEOS OBSERVATIONAL REQUIREMENTS

Simultaneous coverage of ocean areas on the order of 160 x 160 km is required. Among the important geographical sites are: (1) the East Coast of the United States and Nova Scotia, including New England, New York, Cape Hatteras, the Carolinas, and Florida; (2) the Gulf Stream; (3) upwelling regions near San Diego and the Oregon coastline; (4) the Gulf of Mexico coastline.

6. SENSOR REQUIREMENTS

	λ	$\Delta\rho$	ΔT
	.42-.48 μm	1%	
visible channels	.48-.52	1%	
	.52-.58	1%	
	.58-.62	1%	
	.62-.66	1%	
	.66-.70	1%	
IR	10.5-12.5 μm		0.5-1°C

While an EIFOV on the order of 100 m would be desirable, resolution of 200 to 600 meters will give useful information on current dynamics. Thermal band is required.

7. DATA REQUIREMENTS

Data requirements vary with type of phenomena being monitored. Information on ocean conditions that can lead to storm and flood potential should be relayed to user decision centers within a few hours of discovery to activate precautionary procedures, ship routing changes, or to initiate supporting aircraft underflights measurement to verify causal nature of phenomena.

Other measurement data can be daily reported, such as meandering of Gulf Stream with its influences on fishing or pollution pattern meanderings of interest to EPA or the U. N.

8. INTERIM STUDIES

Spacecraft oceanography research must be continued to further refine techniques for deriving useful oceanographic information from remotely sensed data.

Improvements have recently been made in the remote detection and measurement of chlorophyll, water depth, concentration gradients, oil pollution, and sea state. Further interim studies are needed to apply these techniques and develop processing procedures to SEOS data.

9. IMPORTANCE/JUSTIFICATION

This application is justified on the basis of (1) the damage due to natural causes which could be reduced or eliminated by knowledge gained from SEOS observations, and (2) the possibly greater damage that could result from human activity in the ocean if the efforts of this activity are not recognized and effective steps are not taken to correct the situation. The possibilities include destruction of oxygen and food supplies, and catastrophic climate change.

The benefits of this program would be international in scope.

10. SEOS UNIQUENESS

The capabilities of large-scale and continuous coverage provided by SEOS are uniquely and optimally suited to this application. Satellites have already proved valuable in oceanographic studies, but their usefulness for observing dynamic phenomena and for monitoring is limited by their sporadic coverage. This limitation would be effectively removed by a stationary satellite like SEOS.

Ocean dynamics studies with SEOS capability could be revolutionary in establishing the cause-effect and time lag relationships of bio-environmental systems. This may lead to the complete understanding of the transfer of energy between the physical-chemical and biological regimes of the oceans.

Significant dynamic effects such as sea state, surface wind fields, storm surges, large scale ocean circulation, air-sea interaction, tides, and tsunamis could also be effectively studied with SEOS

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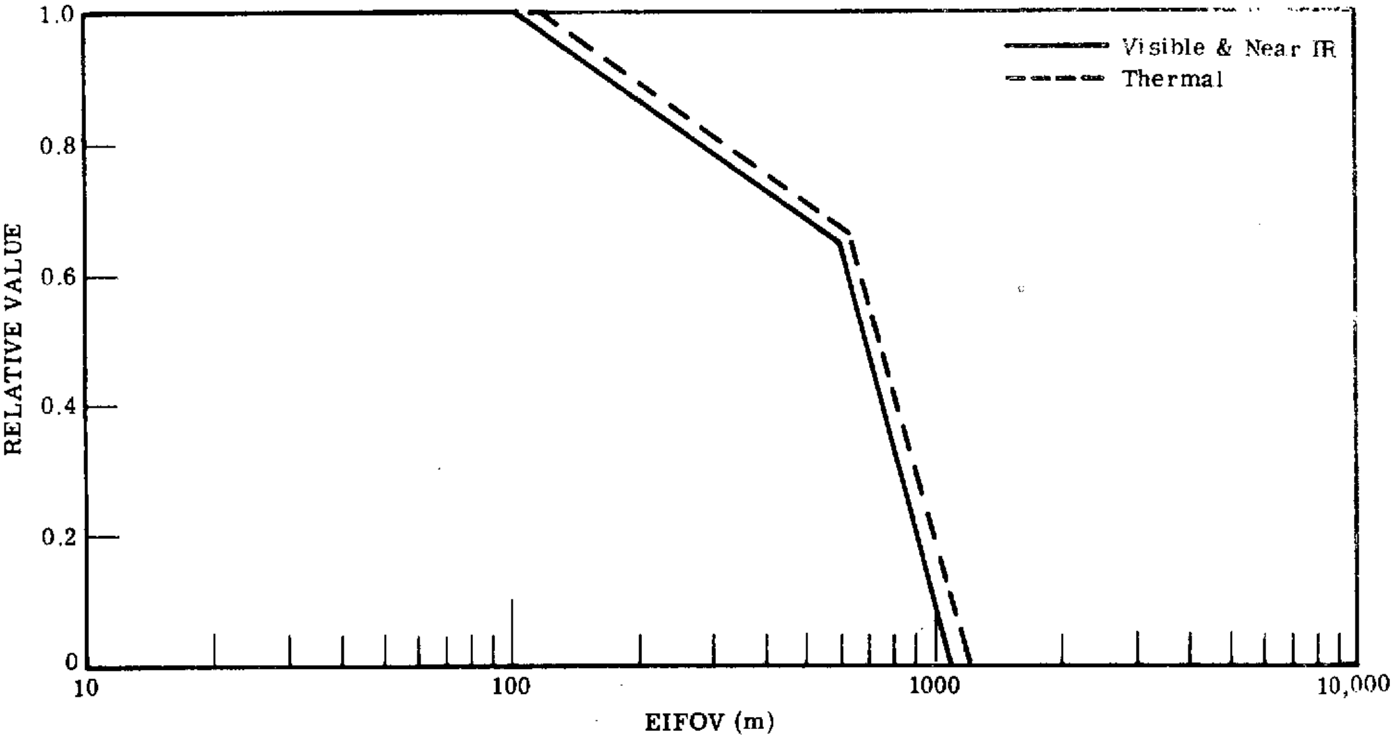
SEOS APPLICATION SUMMARY

ERIM

OCEAN DYNAMICS	APPLICATION	
NOAA, EPA, U.S. Navy, U.S. Department of Interior, U.S. Army Corps of Engineers, United Nations, International Oceanographic Commission, FAO, Department of Transportation, U.S. Coast Guard.	USER	
Ocean color and temperature, sun glitter, cloud patterns Visible and thermal imagery.	OBSERVABLE AND CHARACTERISTICS	
Winter, early and late spring, early and late summer, fall.	Season	TIME LINE OF EVENT
3 observations/day for two-week periods Observation window: 3 hours.	Duration	TIME LINE OF EVENT
6	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
1	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
3 observations per day for 14 day intervals (42)	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
East and West Coast, U.S. Nova Scotia Gulf Stream Gulf of Mexico	Geographic Location	SEOS OBSERVATION REQUIREMENTS
160 x 160 km	Dimensions (m., Km.)	
100 m nominally, See attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
.42-.48 μm .66-.70μm .48-.52 μm 10.5-12.5 μm .52-.58 μm .58-.62 μm Thermal band is required .62-.66 μm	Wavelength Interval (μm)	SENSOR REQUIREMENTS
$\Delta\rho$ = 1%	$\Delta\rho$, ΔT (%, °C)	SENSOR REQUIREMENTS
Imagery (70 mm and 9 inch, positive and negative transparencies) data types.	Format	DATA REQUIREMENTS
4 hours	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Ground & airborne verification & corroboration of anomaly detections Sea State and Meteorological data during observation (including forecasts).	Ancillary Data	DATA REQUIREMENTS
Improvement of techniques for remotely measuring chlorophyll, water depth, suspended particle concentrations, and oil pollution. (A,S, A/C, S/C)	Study	INTERIM ACTIVITIES
120 mm	Level	INTERIM ACTIVITIES
1975-1980	Time Frame	INTERIM ACTIVITIES
A/C, ERTS, Skylab, Nimbus, ITOS, Tiros, SMS	Platform	INTERIM ACTIVITIES
High	IMPORTANCE/ JUSTIFICATION	
Unique and optimum	SEOS UNIQUENESS	



APPLICATION: Ocean Dynamics

E5

DETECTING AND MONITORING FISH DISTRIBUTION AND AVAILABILITY

1. APPLICATION

Assess, monitor, and predict the distribution and abundance of fish stocks having real or potential commercial value and contribute to the efficient utilization and management of the fisheries resources.

2. USERS

Information to be provided by SEOS on probable fish location would be of ultimate use to commercial and recreational fishing interests and to resource management agencies. The National Marine Fisheries Service of NOAA could aid the fishing industry and management agencies by collecting, analyzing and disseminating the information provided by SEOS.

3. OBSERVABLES AND CHARACTERISTICS

A number of characteristics observable from space may indicate the probable location of fish. Kemmerer and Benigno (1973) found that the distribution of photographically detected adult menhaden in the Mississippi Sound was significantly correlated with water color, (an indicator of various nutrients, of plankton upon which fish feed, and of ocean surface anomalies), water depth, surface salinity, and water transparency. Other important observable parameters include sea surface temperature, surface currents, and bioluminescene (Clark and Stone, 1965; Clarke, 1965; Sour, 1965; Stevenson, Atwell, and Maughan, 1972). From these observable differences it is also possible to detect such large scale dynamic features as upwellings, tidal changes, and estuarine circulation which have a bearing of fish concentrations (Maughan, 1973).

Both oceanic fisheries, dependent primarily on tuna, whales, and gamefish, and coastal fisheries, based largely on such species as menhaden, anchovies, and sardines can and should be assessed and monitored remotely. Parameters to be observed will vary between the area as well as the necessary sensor requirements.

If the location and activity of fishing vessels could be observed with reasonable continuity (say weekly), this could be of value in a program for regulation of fisheries. Direct observation of smaller vessels would, however, require resolutions of less than 15 m.

4. TIME LINE OF EVENT

Patterns of dynamic features such as tides and estuarine circulation will change materially during intervals as short as one day. Commercial and recreational fishing activity occurs throughout the year at different times and in different geographical locations, depending on the species involved.

5. SEOS OBSERVATIONAL REQUIREMENTS

The Gulf of Mexico, including the site at which the present ERTS-1 investigation of menhaden fisheries is being conducted, should be a prime site for SEOS research (Stevenson, Atwell and Maughan, 1972). A fishery site in the mid Atlantic and Gulf of Maine and one in the Oregon-Hawaii-Baja California triangle should also be selected where a basis exists for anticipating successful correlation of SEOS observations and fish detection, and which is being actively fished at the present time. The scan range should be moved northward to include the western boundary of Greenland in the Atlantic and a comparable latitude in the Pacific.

For each site, complete spectral and thermal mapping should be done initially for the total target area to verify environmental correlations. Initially, observations should be conducted 6 to 8 times during a 24-hour period. Such diurnal observation will allow an assessment of the extent of the environmental parameters which may have a bearing on fish concentrations and movements. Deployment of sea truth vessels collecting ancillary data will be controlled by the timing of each observation. The set of observations should be repeated daily during the period of the experiment, until the rate at which the critical environmental parameters change is determined.

6. SENSOR REQUIREMENTS

Characteristics or environmental features to be observed especially oceanic, are sizable in nature. Two hundred m resolution in the visible ranges would appear to be adequate at this time for oceanic observations; 50 m resolution is desirable for coastal observations. Detection of specific schools of fish may require a 50 m resolution capability, depending on fish density and distance from the surface. Thermal resolution of 400 m should be sufficient to delineate the larger scale oceanic circulation patterns which may have a bearing on fish concentrations; while 200 m thermal resolution is desired for coastal areas. Thermal sensitivity should be 1°C in coastal waters and 0.5°C in oceanic waters. Thermal is required.

7. DATA REQUIREMENTS

Data should be provided in the form of computer compatible tape within a real time frame of 2 hours or less of the observation. Processing time required for an operational prototype might be as short as thirty minutes or one hour; therefore, consideration should be given to a near real time remote acquisition and preliminary processing station (portable if possible). Imagery should also be provided but it may be at a later date. Meterologic and oceanographic parameters including surface temperature, turbidity, surface currents, salinity and plankton concentration should be measured concurrently with SEOS coverage, at least in the initial stages of the project in order to verify environmental correlations.

8. INTERIM ACTIVITIES

The exact role of satellite information as an aid to fish location still remains to be determined. The ERTS-1 study of the menhaden resource in the Gulf of Mexico, as well as a variety of ERTS-1 studies of coastal waters, will provide needed information on the utility of the information, the parameters to be sensed, and the requirements for an operational capability. However, it must be recognized that the ongoing ERTS fishery study is specific for the Gulf and for menhaden. It will give one data point for the overall data requirement and extrapolation from this to the fish resource in general is questionable. Additional studies of this type in other areas and involving other species are necessary. The applicability of SEOS will depend on the requirements for spectral and thermal resolution, the speed of response indicated by these studies, and the ability of other satellite and/or aircraft systems to meet these requirements. Further, additional work on the development of predictive models for fish distribution and abundance using remote sensing inputs, similar to Kemmerer's work, should be undertaken. This will further define the necessary capabilities of SEOS and its applicability.

9. IMPORTANCE/JUSTIFICATION

Methods of improving the efficiency with which distribution of fish stocks can be ascertained reduces the labor and other operating costs involved in acquiring data applicable to the utilization and management of fisheries resources. The ability of SEOS to observe large areas of ocean would make it possible to apply fish stock distribution and availability information for a sizable fraction of the fishing industry. It should be recognized, however, that increasing catch efficiency may further increase pressure on the fish stocks, and that resource management must be an integral part of fishery utilization. SEOS offers the potential for management of the fisheries resources to an extent not now possible. First, more accurate assessment of the population of a particular species and its habits (information extremely difficult to obtain using present methods with world-wide migratory species whose life cycles are often as yet only imperfectly known) will enable management policies to be set on a more biological basis and thus prevent overfishing - and its economic consequences - and/or possible extermination of a species. Second, the monitoring of fisheries regulations will be more efficient and more feasible. In addition, SEOS may open the way for world-wide management of fisheries resources.

10. SEOS UNIQUENESS

Detection of the probable distribution and availability of fish is information which must be acted on in a relatively short period of time. Delays of more than a few hours may degrade the usefulness of the information. SEOS offers the possibility of critical timing of the observation period, with timing of repeated looks subject only to the interference of cloud cover. A single ERTS satellite would permit looks only at infrequent and inflexible intervals. Geosynchronous satellites launched under other programs may provide some of the needed data described above but the projected resolution capabilities of these satellites is less than that deemed necessary for detection, assessment, and possible prediction of fish distribution, abundance, and availability.

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Maughan, Paul M. 1973 Investigation to improve menhaden fishery prediction. NASA Earth Resources Survey Program. Weekly abstracts. p. 39.

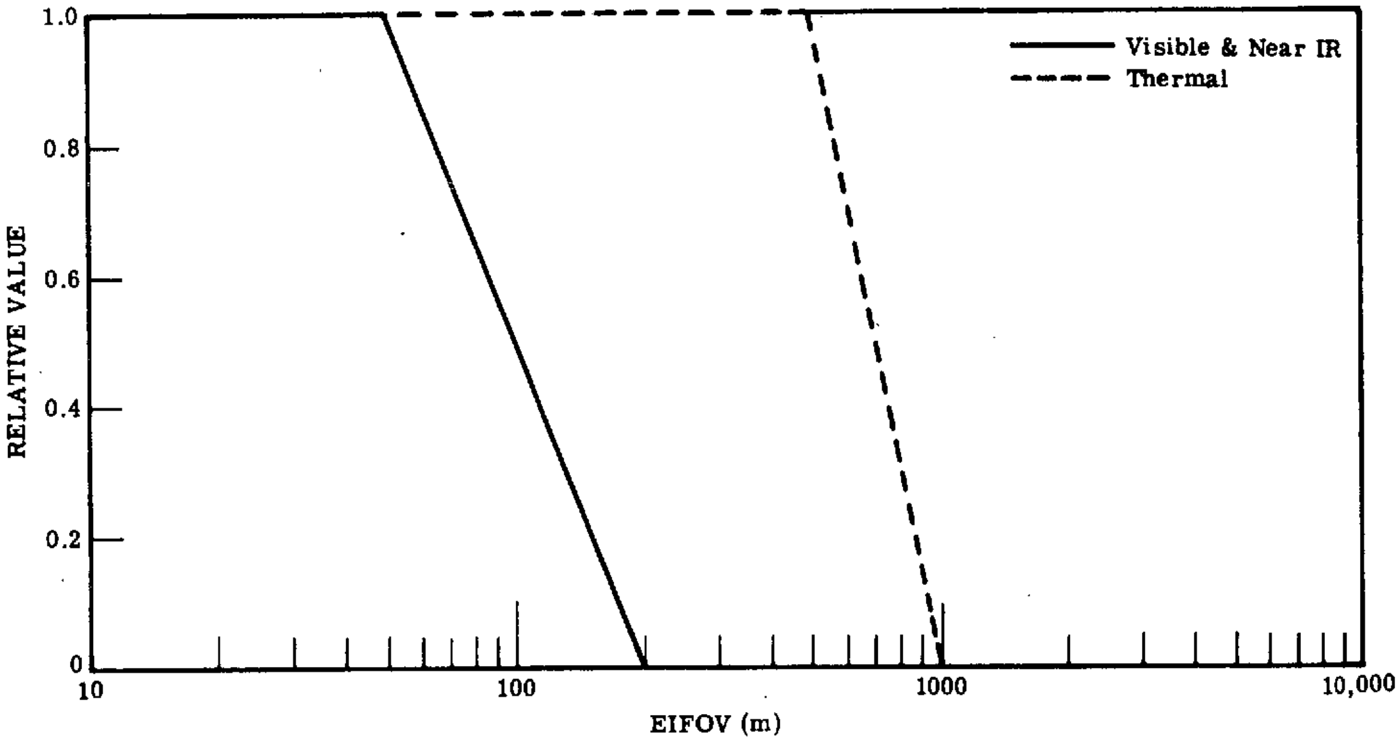
Sour, J.F.T. 1965. Oceanographic observations from manned satellite for fishery research and commercial fishery applications. Oceanography from space. Woods Hole Oceanographic Institution, Woods Hole, Massachusetts. pp. 313-314.

Stevenson, W. H., Atwell, B. H., and Maughan, P. M. 1972. Application of ERTS-1 for fishery resource assessment and harvest. Proceedings of the Eighth International Symposium on Remote Sensing of Environment. Vol. 2. Environmental Research Institute of Michigan, Ann Arbor, Michigan. pp. 1491-1495.

SEOS APPLICATION SUMMARY

ΣERIM

DETECTING AND MONITORING FISH DISTRIBUTION AND AVAILABILITY.	APPLICATION	
National Marine Fisheries Service; commercial and recreational fishing industries; State, National, and international management agencies.	USER	
Sea surface conditions, temperature, color, turbidity; currents, salinitv, deoth; thermal emmission, spectral reflectance	OBSERVABLE AND CHARACTERISTICS	
all	Season	TIME LINE OF EVENT
1 year. Observations over 1wk period (8/day 5)=40 Observations 4wk period (2/day 28)=56 window 4 hrs.	Duration	
2 observations may be variable; e.g., longer time period during the fishing season, shorter duration and small sample rate during the off season, higher rate in the event of sudden changes in the environment.	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
5	No. Targets per Event	
Initially, 6-8 during each 24 hour period daily until the extent of the environmental parameters operating are defined (e.g. 5 days) then one day light (1000=1400 hrs.) and one night (thermal) daily	No. Observ. per Target	
Gulf of Mexico, North Atlantic Coast, Pacific Coast, Oregon, Baja California area, mid-Atlantic and Gulf of Main.	Geographic Location	
500	Dimensions (m., Km.)	
100 m 600 m oceanic	EIFOV (m.)	SENSOR REQUIREMENTS
Six MS bands in 0.4 - 1.0 μm 10.5-12.5 μm Thermal band is required.	Wavelength Interval (μm)	
1% .5°C	Δρ, ΔT (%, °C)	
Computer compatible tapes in real time; imagery may be at a later time	Format	DATA REQUIREMENTS
2 hours or less	Time After Observ. (Da.Wk.Mo.)	
Meteorologic and oceanographic measurements	Ancillary Data	
Analytical study of similar ERTS and EREP experiments and intensive field study of significant parameters prototype forcast systems; predictive modelling.	Study	INTERIM ACTIVITIES
ERTS 60 mm Skylab 60 mm Forcast sys. 120 mm Modelling 120 mm	Level	
1976 1977 1978 1976→	Time Frame	
ERTS Skylab NOAA III SEASAT Shuttle NOAA Series SEASAT All	Platform	
High	IMPORTANCE/ JUSTIFICATION	
Unique	SEOS UNIQUENESS	



APPLICATION: Detecting and Monitoring Fish Distribution and Availability

E6

DETECTING AND MONITORING ICEBERG HAZARDS

1. APPLICATION

The monitoring of icebergs as potential hazards to navigation.

2. USERS

This information will be of direct benefit to the owners, crew of passengers, and users of ships of all nationalities operating in areas of hazardous ice movement. The information will initially be utilized by agencies responsible for trafficking and advising ocean navigation. The primary agency for this is the International Ice Patrol supported by 14 nations and conducted by the U.S. Coast Guard. Other users are the U.S. Navy, the U.S. Air Weather Watch, and similar organizations for Canada, Greenland, Great Britain and other nations.

3. OBSERVABLE AND CHARACTERISTICS

During a year an estimated 10,000-15,000 large icebergs calve from the ice sheets and outlet glaciers of Greenland and Baffin Island. From less than 20 to over 1,000 of these icebergs eventually drift on the Laborador Current into the North Atlantic shipping channels south of Newfoundland (Dyson, 1966). The bergs can begin their existance as several square mile areas and will eventually dissipate. These features can be observed in visible bands, as thermal anomalies, or on radar imagery.

4. TIME LINE OF EVENT/OBSERVABLE

Icebergs may occur throughout the year but are predominant from late spring to early fall.

5. SEOS Observational Requirements

Iceberg sample observations will occur for two time periods of one week each during the summer months. During these periods observations will occur on a daily basis with one day of observations every 6 hours. The inclusion of the one day of more frequent observations can be useful in a detection of rate of drift for these features. While icebergs may be found on several high latitude ocean surfaces, the primary hazard and target area for this study is south of Newfoundland. This area is highly hazardous because of the high frequency of bergs, shipping, and fog in this location. One of the advantages of SEOS is the synoptic view of a large area. Thus a target area of 300 km x 300 km or larger is useful.

6. SENSOR REQUIREMENTS

The optimum EIFOV for iceberg observation is 60 meters or less with over 250 meters of insufficient resolution to be useful. Visible and near infrared bands of ERTS has been useful for iceberg observation and could be duplicated in SEOS. These sensors are of very limited value in areas of heavy cloud cover or fog such as this test site and connot operate at night. (McClain, 1971). For this reason a thermal band of 10.5-12.5 μm with a sensitivity of $1^{o}K$ should be included (Horvath, 1971). The utility of radar with its day/night all weather capabilities for iceberg monitoring is being investigated and may be useful for SEOS. (Bryan, 1972, Johnson, 1971). Thermal is required.

7. DATA REQUIREMENTS

Imagery or overlays of the icebergs would be useful formats for this application. For shipping safety and navigation control, data should be available as soon as possible with a delay of 4-6 hours being reasonable and a miximum usable time return being 24 hours. The only ancillary data needed are a knowledge of shipping channels and schedules which is available to the International Ice Patrol and information on cloud and fog meteorological conditions so as to permit advantageous utilization of visible bands.

8. INTERIM ACTIVITIES

The primary interim activity for this application is the investigation of thermal and radar sensors for iceberg monitoring.

9. IMPORTANCE/JUSTIFICATION

The safety of navigation in the areas of iceberg hazards is very important to many nations, both in terms of economic ease and loss of human life.

10. SEOS UNIQUENESS

The present methodology utilized by the International Ice Patrol has been very successful in preventing losses. However, SEOS has some capabilities which should increase the efficiency of the IIP and also reduce operation costs. These capabilities are the large synoptic view, use of night or cloud penetration sensors, and observation on demand during cloud or fog free periods.

LITERATURE CITED

Bryan, M. L. 1972. The utility of imaging radars for the study of lake ice. Presented at the International Symposia on the Role of Snow and Ice in Hydrology. Banff, Alberta.

Dyson, James L. 1966. <u>The World of Ice</u>. New York: Alfred A. Snopf.

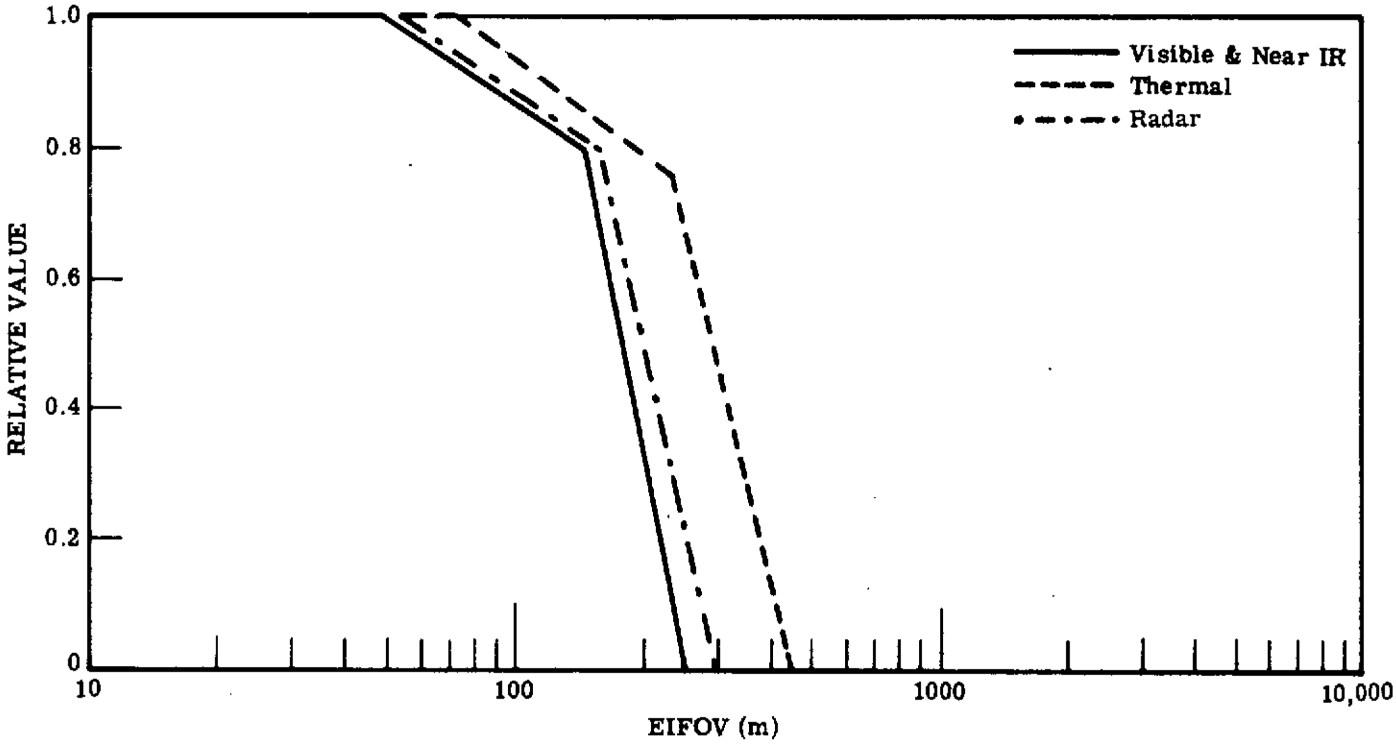
Horvath, R. and W. L. Brown. 1971. Multispectral radiative characteristics of Arctic Sea ice, and Tundra. The Environmental Research Institute of Michigan, Report No. 27980-2-F. Ann Arbor, Michigan.

Johnson, Jimmie D., and Dennis L. Farmer. 1971. Determination of sea ice drift using side looking airborne radar. <u>Proceedings of the Seventh International Symposium on Remote Sensing of Environment</u>, Ann Arbor, Michigan, pp. 2155-2168.

McClain, E. Paul. 1971. Remote sensing of sea ice from earth satellites. <u>Earth Resources Survey Systems, Vol. II</u>. Washington, D.C., pp. 581-594.

SEOS APPLICATION SUMMARY

DETECTING AND MONITORING ICEBURG HAZARDS	APPLICATION	
International Ice Patrol, U.S. Navy, U.S. Air Weather Watch, Shipping and charter boat industry, Fishing industry	USER	
Icebergs; spectral anomalies against ocean background in visible bands; thermal anomalies, radar imagery.	OBSERVABLE AND CHARACTERISTICS	
All; especially late spring to early fall	Season	TIME LINE OF EVENT
2 mos, 1 obs./day for 2 one-week intervals. Observation window: 2 hrs.	Duration	TIME LINE OF EVENT
2	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
1	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
Daily for 1-week intervals with 1 day of observation every 6 hours. (10)	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
South of Newfoundland	Geographic Location	SEOS OBSERVATION REQUIREMENTS
300 km x 300 km	Dimensions (m., Km.)	
60 m. nominal, See attached graph.	EIFOV (m.)	SENSOR REQUIREMENTS
10.5-12.5μm bands in .4-1.1μm range radar Thermal band is required.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
$\Delta T = 1°K$ $\Delta\rho = 3\%$ S/N = 1	$\Delta\rho$, ΔT (%, °C)	SENSOR REQUIREMENTS
Imagery and overlays	Format	DATA REQUIREMENTS
4 hours	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Cloud and fog conditions over target	Ancillary Data	DATA REQUIREMENTS
Use of thermal and radar sensors for iceberg detection (A, F, A/C, S/C)	Study	INTERIM ACTIVITIES
24 mm	Level	INTERIM ACTIVITIES
1975-1978	Time Frame	INTERIM ACTIVITIES
Aircraft, ERTS-B, other satellites	Platform	INTERIM ACTIVITIES
low to medium	IMPORTANCE/ JUSTIFICATION	
Not unique but more economical	SEOS UNIQUENESS	



APPLICATION: Detecting and Monitoring Iceberg Hazards

APPENDIX F

Environment

F1

DETECTING AND MONITORING THERMAL WATER POLLUTANTS

1. APPLICATION

Documentation of thermal conditions in water bodies, particularly nearshore areas of lakes and oceans. Detecting and monitoring thermal intrusions from cooling water discharges or tributary streams.

2. USERS

All levels of government (such as federal, state, and municipal environmental protection agencies) concerned with enforcing legislation and controlling levels and locations of pollution emissions. This information will also be useful to power companies involved in the optimum location and operation of power plants.

3. OBSERVABLE AND CHARACTERISTICS

Documentation of existing thermal conditions in water bodies, particularly near shore areas of large lakes and oceans, is a necessary prerequisite for water quality modelling and for planning municipal, industrial, and recreational uses of water bodies. The observables are intrusions of water bodies of different temperatures from cooling water discharges and tributary streams. These intrusions can be observed in different circulation patterns under varied wind speeds, directions, and water temperatures (Polcyn, 1972; Strong, 1971).

4. TIME LINE OF EVENT/OBSERVABLE

These processes are continuous but may have large variations under different meteorological and hydrologic conditions. They should be monitored in different seasons to observe the thermal dynamics in as many situations as possible.

5. SEOS OBSERVATIONAL REQUIREMENTS

For this application, test sites will be southern Lake Michigan, the New York Bight and Jersey coast, and the coast of southern California. The

Lake Michigan site is chosen because of large numbers of existing and projected power plants, heavy population centers, and numerous tributaries into the lake. This site is complicated by the spring development of a thermal bar concentrating effluents near shore and a large seasonal climatic change. This site also allows the opportunity to monitor the effect of thermal discharges on lake ice. The southern California site has fewer tributary streams and less climatic change, but has several important locations of thermal discharge and an ocean circulation with stronger tides than the Lake Michigan site. The New York Bight and Jersey coast site is an area of very complex water quality and thermal problems particularly affected by tidal action. A geosynchronous satellite could perform several functions in observing these sites. It could continuously monitor these sites for any sudden changes in thermal conditions; it can provide records of existing thermal conditions as a basis of comparison to later developments; and it could monitor these areas intensely for short periods under different parameters to provide data in developing models. To display the applicability of SEOS for these functions, observations should occur at each of these sites for four five-day periods to coincide with seasonal variability. During these periods, observations should be made at four hour intervals to assess diurnal variation in target to background contrast. The target size for all sites should be 150 km x 150 km.

6. SENSOR REQUIREMENTS

An EIFOV of the same magnitude as present ERTS imagery is adequate for these functions. Smaller resolution elements would be of additional benefit while a resolution greater than 250 meters would not provide sufficient detail for observing or modelling thermal circulation patterns. A thermal band of 10.5-12.5 μm with a sensitivity of 1°K is useful for this application (White, 1971). Thermal band is required.

7. DATA REQUIREMENTS

Imagery and thermal slices are useful formats. For a system primarily designed for gathering information for model building, there is no severe time restraint on data return. However, for detecting violations and enforcing regulations, a maximum of 1 day would be required. Ancillary data of meteorological and hydrologic conditions, most of which may be obtained from existing collection agencies, is necessary for meaningful interpretation.

8. INTERIM ACTIVITIES

Research on the nearshore circulation patterns of water bodies of different temperatures and the effects of additions of warm water bodies on water quality and plankton growth are essential.

9. IMPORTANCE/JUSTIFICATION

The need of greater environmental control is gaining higher priorities as the severity of some of our environmental problems is becoming more apparent. Thermal discharges can contribute to environmental change of the chemical, physical, and biological processes in water bodies. A documentation of existing thermal conditions is a prerequisite for accessing the impact of presentor proposed thermal discharges, for water quality monitoring and control, and for planning uses of the water body. Knowledge of the temporal and spatial distribution of thermal discharges is vital to the management and regulation of these bodies. The methodology derived would have international applicability.

10. SEOS UNIQUENESS

The ability of SEOS to provide repeated large scale imagery of an area at short time intervals is extremely valuable for a dynamic system. The added ability to take observations on demand in cloud free conditions increase the uniqueness of SEOS.

LITERATURE CITED

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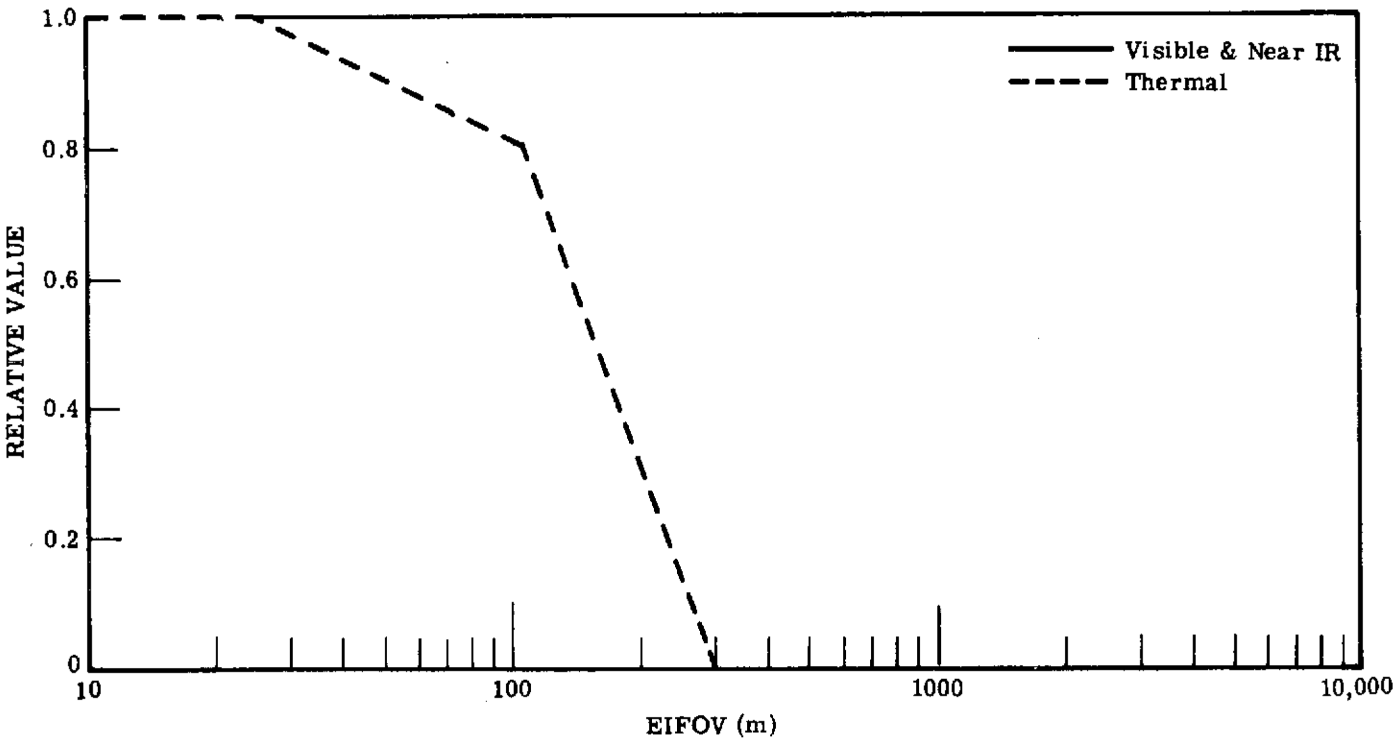
Strong, A. E., D. R. Baker, and G. Irbe. 1971. Mapping surface temperatures on the Great Lakes from satellite infrared data. 14th Conference Great Lakes Research.

White, P. G. 1971. Remote sensing of water pollution. Earth Resources Survey Systems, vol. II. Washington, D. C. U. S. Government Printing Office, pp. 303-322.

SEOS APPLICATION SUMMARY

ERIM

DETECTING AND MONITORING THERMAL WATER POLLUTANTS	APPLICATION	
Environmental Protection Agencies, Power Companies, Conservation and Environmental Action Groups, State Departments of Natural Resources, state and municipal environmental protection agencies.	USER	
a) intrusion of water bodies of different temperatures from cooling water discharges and tributary streams. b) water variations.	OBSERVABLE AND CHARACTERISTICS	
all	Season	TIME LINE OF EVENT
--1 yr. observations over 4 five-day intervals. Observ Window 2 hrs.	Duration	TIME LINE OF EVENT
4 (at least one set of observations each season)	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
2	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
observations at 4 hour intervals for five-day periods (30)	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Southern Lake Michigan Southern California Coast	Geographic Location	SEOS OBSERVATION REQUIREMENTS
Lake Michigan 150 km x 150 km California 150 km x 50 km	Dimensions (m., Km.)	
25 m. nominally, See attached graph	EIFOV (m.)	SENSOR REQUIREMENTS
Thermal 10.5 - 12.5μm Thermal band is required.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
1°K	Δρ, ΔT (%, °C)	SENSOR REQUIREMENTS
Imagery with thermal slicing overlays computer compatible tapes.	Format	DATA REQUIREMENTS
1 day	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
meteorological and hydrologic parameters during observations	Ancillary Data	DATA REQUIREMENTS
analytical study of nearshore circulation patterns and effects of warm water on water quality and plankton growth (A,F,A/C)	Study	INTERIM ACTIVITIES
24 mm	Level	INTERIM ACTIVITIES
1976-1978	Time Frame	INTERIM ACTIVITIES
field, A/C	Platform	INTERIM ACTIVITIES
Medium to high	IMPORTANCE/ JUSTIFICATION	
Unique	SEOS UNIQUENESS	



APPLICATION: Detecting and Monitoring Thermal Water Pollutants

F2

DETECTING AND MONITORING OF WATER-SUSPENDED SOLID POLLUTANTS

1. APPLICATION

The detection of water pollution such as ocean dumpings, municipal sewage, or industrial effluent and mapping the source and dispersion of such suspended solids.

2. USERS

Information concerning suspended solid materials is of interest to government agencies concerned with or responsible for water quality. Examples of these users are port authorities, state or local natural resource departments, local and U. S. Public Health Service, the U. S. Environmental Protection Agency, the International Joint Commission on the Great Lakes, NOAA, U. S. Coast Guard, and numerous groups such as the Delaware River Basin Commission. Individuals, citizen groups, and industries may also utilize such information.

3. OBSERVABLE AND CHARACTERISTICS

Suspended solids diffuse in water from their source or sources under the influence of water currents and wind direction and velocity. The pattern of diffusion is determined by changing hydrologic and meterological parameters. The spatial extent of such effluents is highly variable. Suspended solids in water changes the apparent spectral reflectance, i.e., upwelling radiation (White, 1971).

4. TIME LINE OF EVENT/OBSERVABLE

These effluents may be continuous such as sediments from rivers or random temporal features such as ocean dumps and dredging operations. SEOS should demonstrate the capability to monitor both of these situations.

5. SEOS OBSERVATIONAL REQUIREMENTS

For this application, western Lake Erie and the Delaware Bay are selected test sites to illustrate the feasibility of SEOS to operate under varied conditions and for various types of water pollutants. Western Lake Erie receives a large volume of suspended solids from the Maumee and Detroit Rivers. The heavy pollution centers around the lake and various types of land use result in a highly varied type and level of pollutant load. Lake Erie is of further interest because of the concern of the International Joint Commission on the movement of pollutants across the international boundaries of the Great Lakes. Delaware Bay was chosen as a test site because of the strong tidal influence on dispersion patterns and the intermittant dumping of one type of pollutant, i.e., sewage sludge. Sewage sludge is not simply a suspended solid but this application can be used to assess the usefulness of SEOS for several categories of water pollutants. Target areas for both sites are 100 km x 100 km. SEOS observations may be used to perform several functions. The data may be used to document authorized discharges and to ascertain compliance in location and amount, to document the dynamic nature of the buildup and movement of these effluents, to aid in model development, to detect and control illegal discharges, and to provide information for planning and management decisions. These sites should be observed every four hours for four separate five-day periods to provide data on circulation patterns under different parameters especially tidal conditions.

6. SENSOR REQUIREMENTS

Visible bands, especially .5-.6 and .6-.7 μm will provide the best information on suspended solids (Klemas, et al., 1973). An additional visible band of .4-.5 μm and a near infrared band of .8-1.1 μm will also provide useful information for specific pollutants. An EIFOV as large as 100 meters if valuable for this purpose, but resolution exceeding 300 meters, would be of questionable value.

7. DATA REQUIREMENTS

Imagery and overlays for visual inspection, density slicing, and multispectral analysis are desired formats for suspended solids investigations. For the purpose of data collection on circulation dynamics a rapid data return is not necessary. However for detection of discharge violations and enforcing compliance with legal regulations, a maximum of one day is required. Meteorological data from available collection agencies and water samples during SEOS observations are needed ancillary data.

8. INTERIM ACTIVITIES

Required interim activities include an investigation of the effects, controls, and maximum limitations of water pollutants.

9. IMPORTANCE/JUSTIFICATION

The concern for pollution of inland and estuarine waters by man's waste also extends to the open seas. As the production of waste material increases, larger disposal areas are sought and, simultaneously, more concentrated disposals occur. Further, uncontrolled use of water bodies as a disposal area may have serious health, esthetic, and economic consequences. An example of the significance to public health of sewage sludge, dumped in deep seawater, is the possible contamination of surf clams which may later be harvested for human consumption. Shellfish are also capable of concentrating and holding bacteria, viruses, and toxic substances that they ingest from their marine environment. In turn they can transmit these concentrations to consumers of the shellfish (Buelow, 1968). To aid in this and other water pollutant controls, more information on the dynamics of pollution and a monitoring system to assure dumping in areas not destructive to fisheries, recreation areas, and public water supplies are needed. This is a function SEOS can perform.

10. SEOS UNIQUENESS

The capability for critically timed monitoring of specific areas and effluents for extended periods is unique and further, has several features which make it more valuable and perhaps more economical than other sensors. These features are large area coverage, sequential coverage, and monitoring on demand.

LITERATURE CITED

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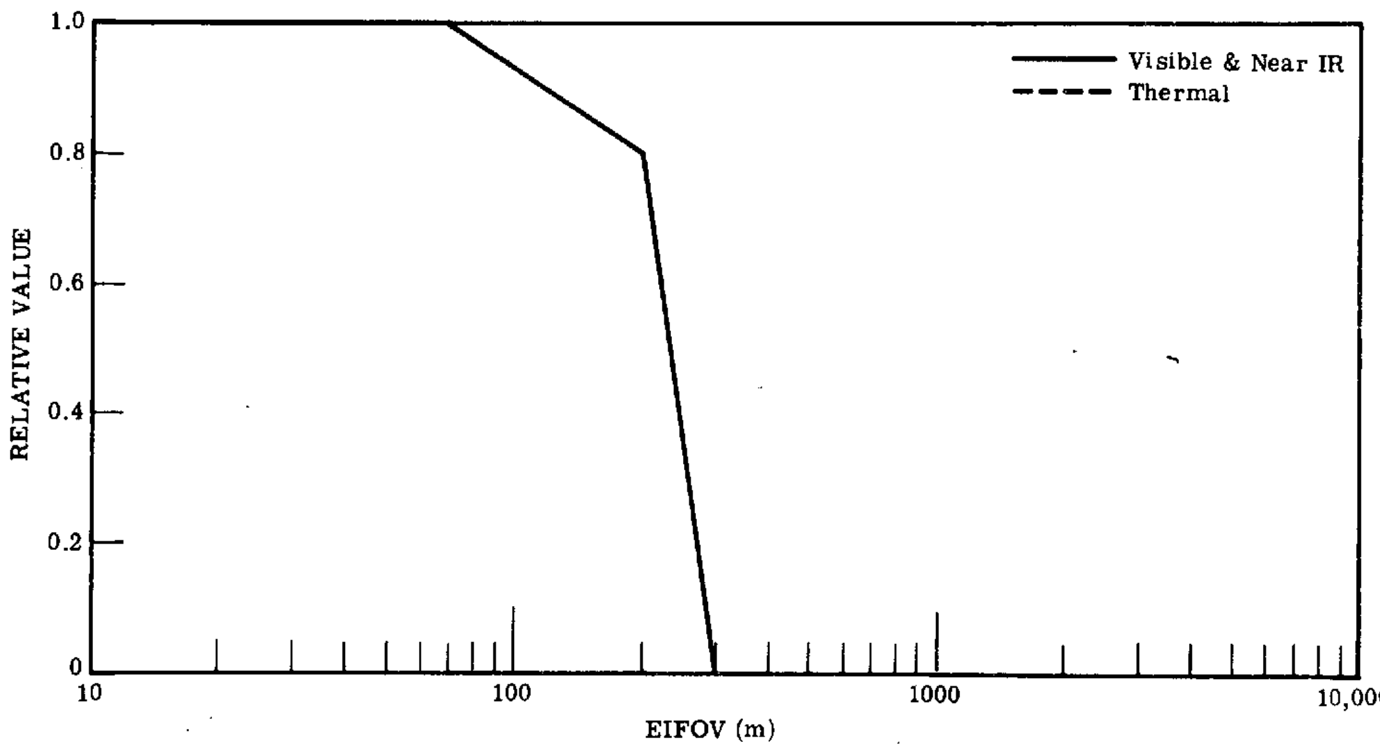
White, Peter G. 1971. Remote Sensing of water pollution. Earth Resources Survey Systems, Vol. II, Washington, D. C. pp. 303-322.

SEOS APPLICATION SUMMARY

ERIM

DETECTING AND MONITORING OF WATER-SUSPENDED SOLID POLLUTANTS	APPLICATION	
Environmental Protection Agencies, U.S. Public Health Service, U.S. Coast Guard, International Joint Commission of the Great Lakes, Delaware River Basin Commissions, Industrial concerns of most cities, fisheries industry, NOAA.	USER	
Plumes of pollutants in water, identifiable through pixel spectra yielding color differentiation.	OBSERVABLE AND CHARACTERISTICS	
all	Season	TIME LINE OF EVENT
1 year. Observations over 4 five-day intervals. Observ. Window: 2 hrs.	Duration	TIME LINE OF EVENT
4 (at least one set of observations each season)	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
2	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
Observations at 6-hour intervals for five-day periods (20)	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Western Lake Erie Delaware Bay	Geographic Location	SEOS OBSERVATION REQUIREMENTS
100 km x 100 km	Dimensions (m., Km.)	
70 m nominally, See attached graph	EIFOV (m.)	SENSOR REQUIREMENTS
.4-.5 μm .5-.6 μm .6-.7 μm .8-1.1 μm	Wavelength Interval (μm)	SENSOR REQUIREMENTS
$\Delta\rho$ = 1%	$\Delta\rho$, ΔT (%, ^{o}C)	SENSOR REQUIREMENTS
Imagery and overlays, computer compatible tapes.	Format	DATA REQUIREMENTS
1 day	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Meteorologic and hydrologic data during observations.	Ancillary Data	DATA REQUIREMENTS
An analysis of the effects and controls of water-suspended solid pollutants	Study	INTERIM ACTIVITIES
12 mm	Level	INTERIM ACTIVITIES
1976-1977	Time Frame	INTERIM ACTIVITIES
ground	Platform	INTERIM ACTIVITIES
high	IMPORTANCE/ JUSTIFICATION	
Unique due to requirement for repeated observation over extended periods.	SEOS UNIQUENESS	



APPLICATION: Detecting and Monitoring of Water-Suspended Solid Pollutants

F3

DETECTING AND MONITORING OIL POLLUTION

1. APPLICATION

Detecting and monitoring accidential or intentional oil spills or leaks on water surfaces.

2. USERS

All levels of government and citizen groups concerned with enforcing legislation on, and controlling levels and locations of pollutant discharges. The Coast Guard and the Environmental Protection Agency have primary responsibility for enforcing water pollution legislation in the U. S. and could be prime users. Other users would be port authorities, Army Corps of Engineers, and major oil companies interested in monitoring and controlling potential leaks or spills from their own wells or tankers. Since oil wells and oil tankers are located throughout the world, there is a broad spectrum of potential users.

3. OBSERVABLE AND CHARACTERISTICS

The specific features to be observed on water bodies are oils from leakage of offshore wells, natural oil spills or seepage, intentional dumping by ships, breaking of pipelines, industrial discharges, or accidents of large oil tankers. From these sources the oil spreads out as a film on the water surface. The spatial and temporal extent of these films are dependent upon the amount of oil spilled, wind and current conditions, and the efforts of man in controlling them. The oil may be observed as a variation from ambient water temperatures or as variations in spectral response of the water surface.

4. TIME LINE OF EVENT/OBSERVABLE

These events have an equal probability of occurring at any time and the feasibility of monitoring them on that basis should be demonstrated.

When a spill is detected, SEOS should provide coverage until the event is either dissipated or controlled, a period of several hours to several weeks.

5. SEOS OBSERVATIONAL REQUIREMENTS

For this application, there will be two specific test sites and two targets of opportunity. The two specific sites are offshore drilling in the Gulf of Mexico and the Santa Barbara Channel, also locations of natural seepage. The primary function of SEOS in these locations is to demonstrate ability to detect oil and then assist in providing information for controlling the spill. These sites should be monitored once a day for two separate one-week periods. The target area will be 50 km x 50 km for Santa Barbara and 100 km x 50 km for the Gulf of Mexico. The targets of opportunity are to demonstrate the ability of SEOS to focus on an accidental spill such as a tanker collision. These sites would be monitored every four hours for as long as is necessary on a target area of 50 km x 50 km.

6. SENSOR REQUIREMENTS

Ultraviolet reflectance provides good contrast for oil/water discrimination. However, because of atmospheric attenuation and scattering, it is of doubtful value to sensors carried in a geosynchronous satellite. (Munday, et al., 1971). If further research can overcome the attenuation of UV reflectance, a UV band should be included in SEOS. SEOS should include a thermal band of 10.5-12.5 μm with a sensitivity of 1°K. Some visible and near infrared bands may also be useful (Aukland, 1971; Guinard, 1971). Resolution up to 200 meters is very useful and a resolution of 500 meters has utility for major oil slicks. Thermal band is required.

7. DATA REQUIREMENTS

Imagery and computer compatible tapes are the best formats for this application. For effective response to leakage and targers of opportunity monitoring a data return time of no more than 4 hours is necessary. For a monitoring system designed primarily to provide legal documentation of pollutants and to enforce compliance, the time constraints are some what less severe, being perhaps 12 hours. No ancillary data other than geographic coordinates and that derived from circulation studies and field checking signatures are necessary.

8. INTERIM ACTIVITIES

The primary interim activity is the investigation of other systems for oil detection, satellite use of UV reflectance for oil detection, and more effective methods and controls for oil spills.

9. IMPORTANCE/JUSTIFICATION

The expanding energy needs of an industrialized society have served as a stimulus for increased oil exploration and oil field development. The expansion of oil exploration and production into tidal and coastal regions has increased the likelihood of major oil spills. Additionally, the fact that most of the world's oil production is transported in large tankers to serve the markets of the world, creates a very real potential for large scale oil spills.

The well-publicized Torrey Canyon, Ocean Eagle, and Santa Barbara episodes exemplify the magnitude of the problem. Serious damage to water-fowl and aquatic life, as well as extensive damage to beaches, can occur from such accidents despite attempts to contain the oil spills. As more and more advances are made in the technology of containing and dispersing oil slicks, the major concern becomes one of locating oil slicks at sea so that corrective measures can be taken before serious damage is done (Thamen, 1972).

Both the Federal Government and industry are working to develop solutions to this problem. It is recognized that the potential for oil pollution in an industrial world exists anywhere oil is produced, transferred, or used. Control of the problem requires a rapid and flexible surveillance system for enforcement purposes and the effective control of spill cleanup. SEOS may provide such a surveillance which would have high esthetic, ecological, and economic returns.

10. SEOS UNIQUENESS

The ability to immediately monitor targets of opportunity and continuously monitor possible polluters is unique to SEOS. Further, SEOS may be able to perform these functions more efficiently and more economically than any other available system.

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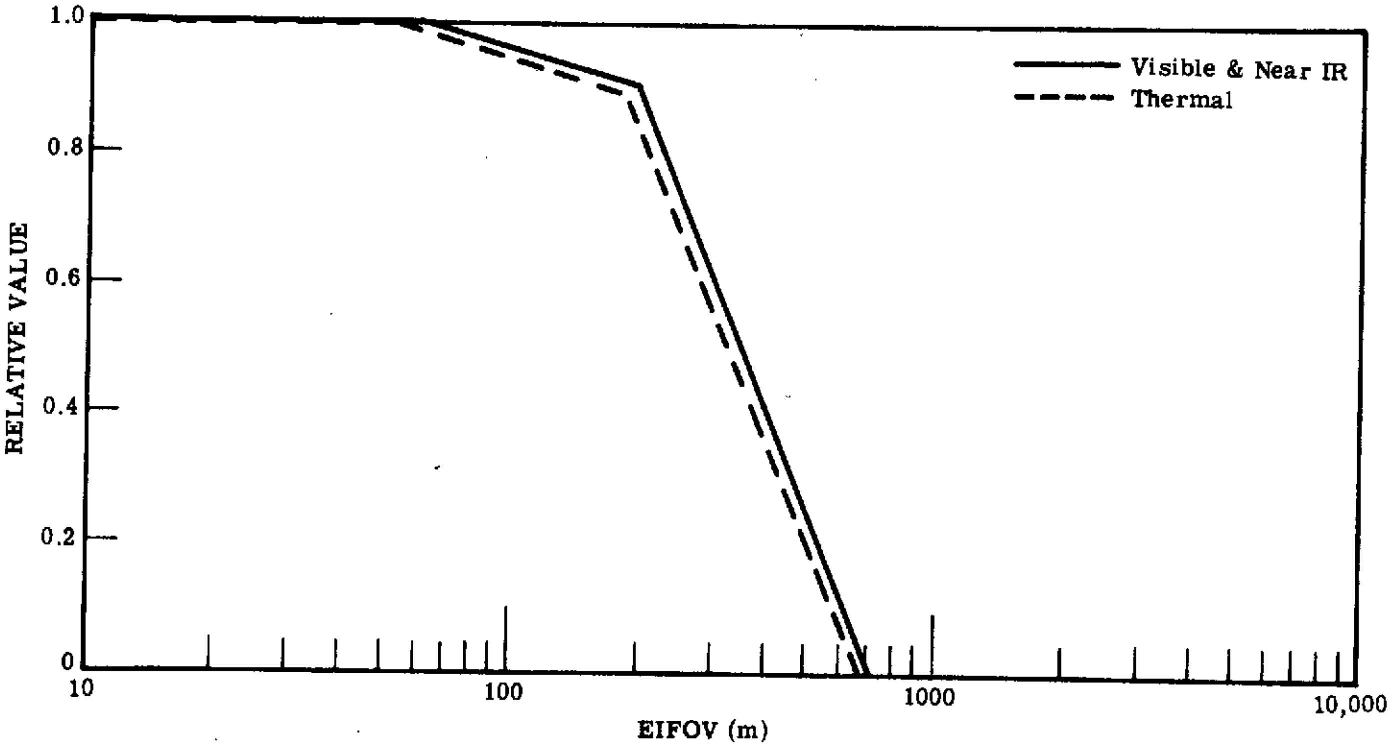
ΣERIM

SEOS APPLICATION SUMMARY

DETECTING AND MONITORING OIL POLLUTION	APPLICATION	
U.S. Coast Guard, Environmental Protection Agency, Army Corps of Engineers, Major oil companies, Citizen groups, Port authorities, & fishing industry.	USER	
Oil films on water surfaces, observed as variations from ambient water temperature (i.e., thermal differences) or as variations in visible and near infrared reflectance (i.e., spectral difference)	OBSERVABLE AND CHARACTERISTICS	
All	Season	TIME LINE OF EVENT
1 year Observations for 2 one-week periods and for two targets of opportunity. Observation window: 2 hours.	Duration	TIME LINE OF EVENT
	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
2 scheduled events and 2 targets of opportunity	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
Observations once daily for a week on scheduled targets (7). For targets of opportunity every 4 hours for one week (168)	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Scheduled events: Gulf of Mexico, Santa Barbara Channel	Geographic Location	SEOS OBSERVATION REQUIREMENTS
Gulf - 100 km x 50 km Santa Barbara = 50 km x 50 km	Dimensions (m., Km.)	
60 m nominally, See attached graph	EIFOV (m.)	SENSOR REQUIREMENTS
10.5 - 12.5μm 0.4 - 0.8μm(multiple bands) Thermal band is required.	Wavelength Interval (μm)	SENSOR REQUIREMENTS
$\Delta\rho$ = 1% ΔT = 1°K	$\Delta\rho$, ΔT (%, °C)	SENSOR REQUIREMENTS
Imagery, computer compatible tapes	Format	DATA REQUIREMENTS
4 hours.	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Geographic coordinates of detections. Field checked signatures of SEOS alerts.	Ancillary Data	DATA REQUIREMENTS
Analysital development and testing of other monitors and methods of oil control and cleanup	Study	INTERIM ACTIVITIES
24 mm	Level	INTERIM ACTIVITIES
1976-1978	Time Frame	INTERIM ACTIVITIES
Ground, A/C	Platform	INTERIM ACTIVITIES
High	IMPORTANCE/ JUSTIFICATION	
Unique	SEOS UNIQUENESS	



APPLICATION: Detecting and Monitoring Oil Pollution

F4

ANALYSIS OF UNDESIRABLE HEAT ISLANDS IN URBAN AREAS

1. APPLICATION

It is useful to analyze urban climates in terms of energy systems. It gives quantitative insight into the disposal of solar energy by distinctive urban surfaces. Streets between rows of buildings become "thermal canyons". Study of the thermal cavity structure of a city may suggest that a variety of building heights along a given street is preferable to the common canyon structure which interfers with ventilating winds, creating problems of excess temperature and stagnation of air (Pease, 1971).

Proper spacing of high-rise buildings can reduce this interference, improve the temperature environment, and reduce the collection of atmospheric pollutants. Reducing these sources of irritants has shown to improve working efficiency and to improve the social environment overall. Measurement of conditions of net radiation may also suggest the most effective location for greenbelts and open spaces in a particular city situation (Whyte, 1968).

2. USERS

City planners
City foresters
Community action groups

3. OBSERVABLE AND CHARACTERISTICS

Radiation observables of importance are thermal contours of urban areas during periods of normal late-summer high temperatures to define heat islands.

4. TIME LINE OF EVENTS/OBSERVABLE

Observations should be made during mid- to late-summer, under normal weather conditions.

5. SEOS OBSERVATIONAL REQUIREMENT

To assess reliability of detection, 4 observations are needed over 3 months on the 10 cities selected. The time of observation should be 1600 hours local time. Geographical coordinates are those of Chicago, Detroit, Houston, Los Angeles, New York, Philadelphia, Atlanta, Seattle, San Francisco, St. Louis and Washington, D. C. Target size is 30 x 30 km.

6. SENSOR REQUIREMENTS

λ	ΔT
10.5 - 12.5 μm	2°K

7. DATA REQUIREMENTS

Overlays of isothermal areas at the same scale as municipal maps.

8. INTERIM ACTIVITIES

Analytical and field study of urban climatology as affected by structures and greenbelts.

9. IMPORTANCE/JUSTIFICATION

A lack of consideration of the factors affecting urban-regional climates has allowed the development of one of the undesirable features of the urban environment. Repetitive synoptic radiation maps will enable governments to assess present conditions and replace aimless drift with wisely planned change. Increased attention to these factors can thus have a high social value.

10. SEOS UNIQUENESS

SEOS capability is unique in that it can obtain data at the discretion of the investigators by both day and hour, permitting a systematic and controlled study.

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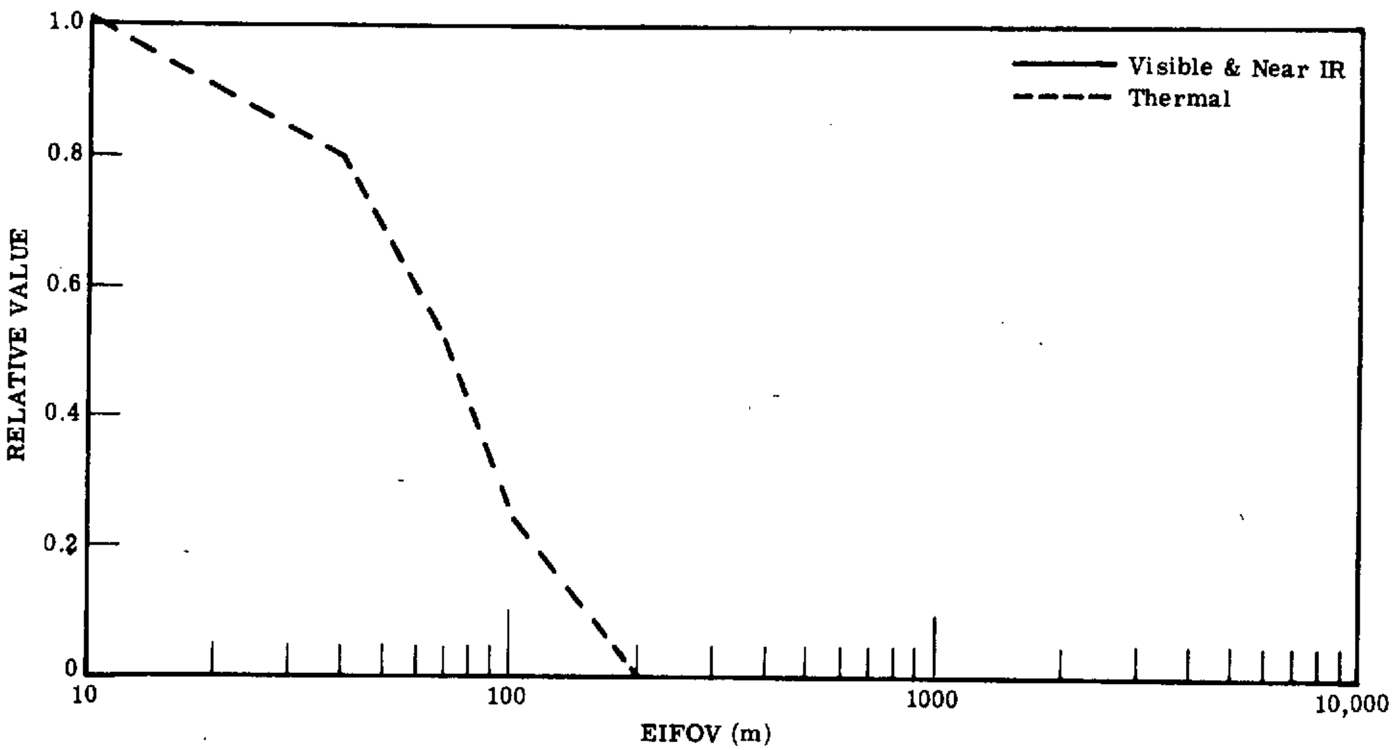
SEOS APPLICATION SUMMARY

ERIM

ANALYSIS OF UNDESIRABLE HEAT ISLANDS IN URBAN AREAS	APPLICATION	
City planners; community action groups; city foresters	USER	
a) Internal temperature environment of urban areas	OBSERVABLE AND CHARACTERISTICS	
Summer	Season	TIME LINE OF EVENT
3 mo. Observation window: 2 hrs.	Duration	TIME LINE OF EVENT
1	Min. No. Events	SEOS OBSERVATION REQUIREMENTS
10	No. Targets per Event	SEOS OBSERVATION REQUIREMENTS
4	No. Observ. per Target	SEOS OBSERVATION REQUIREMENTS
Chicago, Detroit, Houston, Los Angeles, New York, Philadelphia, St. Louis, Washington, D.C., Atlanta, Seattle, San Francisco.	Geographic Location	SEOS OBSERVATION REQUIREMENTS
30 km x 30 km.	Dimensions (m., Km.)	
10 m nominal; See attached graph	EIFOV (m.)	SENSOR REQUIREMENTS
10.5 - 12.5 μm	Wavelength Interval (μm)	SENSOR REQUIREMENTS
$\Delta T = 2°$	$\Delta\rho$, ΔT (%, °C)	SENSOR REQUIREMENTS
Overlays of isothermal areas at the same scale as municipal maps.	Format	DATA REQUIREMENTS
6 months	Time After Observ. (Da.Wk.Mo.)	DATA REQUIREMENTS
Municipal maps	Ancillary Data	DATA REQUIREMENTS
Analytical and field study of urban climatology as affected by structures and greenbelts (A/F/A/C)	Study	INTERIM ACTIVITIES
24 mm	Level	INTERIM ACTIVITIES
1975-1977	Time Frame	INTERIM ACTIVITIES
A/C, Field	Platform	INTERIM ACTIVITIES
Very high social value	IMPORTANCE/ JUSTIFICATION	
Unique; due to both a day and time requirement	SEOS UNIQUENESS	



APPLICATION: Analysis of Undesirable Heat Islands in Urban Areas

APPENDIX G

Potential Short Lived Phenomena Applications For SEOS
Compiled From the Smithsonian CSLP

APPENDIX G

POTENTIAL SHORT LIVED PHENOMENA APPLICATIONS FOR SEOS COMPILED FROM THE SMITHSONIAN CSLP

Short lived phenomena may be classified as environmental events which have lifetimes of a day or less or which vary markedly in degree or character within one days time. These events may be local (oil spill, volcanism) or may extend over large areas (flooding, haze), but all are of short duration or change rapidly in character or intensity, and require either immediate detection or monitoring. The SEOS system is uniquely suited to observing large area phenomena, employing remote sensing with long dwell-times and rapid repetition rates in conjunction with remote readout of in situ sensors, as cloud cover permits.

Since 1968 the Smithsonian Institution has maintained a Center for Short Lived Phenomena (CSLP). The center is located in Cambridge, Massachusetts, where it operates a global environmental alert system for the rapid communication of scientific data on short lived phenomena of the natural environment. The center communicates data and information on transient events selected on the basis of the following criteria:*

"1. Earth Sciences Events: Earthquakes greater than magnitude 7.0 or earthquakes occurring in unusual areas or those creating exceptional interest. Crustal movements, faulting and fissuring, major land movements and landslides.

Volcano eruptions, submarine eruptions, the birth of new islands, island eruptions, the disappearance of islands, fissure extrusions, nuees ardentes, and major mudflows.

Earthquakes under the sea floor greater than magnitude 7.0 or having considerable effect on the marine geophysical environment. Island earthquakes, tsunamis, sea surges, and severe storm erosion.

Polar and subpolar events, formation of ice islands, unusual sea ice break-ups, surging glaciers, and sudden release of glacier-dammed water.

*CSLP Annual Report and Review of Events, 1972, Smithsonian Institution CSLP, Cambridge, Massachusetts, 1973.

"2. Biological Sciences Events: Sudden changes in biological and ecological systems, invasion and colonization of new land by animals and plants, rapid migrations, unusually abundant reproduction or death of vegetation, establishment or reestablishment of flora and fauna.

Severe climatic changes affecting ecosystems, ecological aftereffects of short-term human intrusion into an area previously unvisited by man, and potentially imminent species extinction.

Sudden changes to marine and aquatic environment, oil-pollution, unusual occurrences of marine vegetation, marine bioluminescence, red tides, plankton blooms, and fish kills.

"3. Astrophysical Events: Large fireball events, meteorite falls, and crater-producing impacts. Transient lunar events: obscurations on lunar surface, brightenings, lunar volcanic activity, moonquakes, and meteorite impacts recorded by implaced lunar seismometers.

"4. Urgent Archaeological Events: Discovery of archaeological sites threatened with imminent destruction.

"5. Urgent Anthropological Events: Newly discovered tribes; rapid changes in human ecological systems; short lived acculturation; dying languages, customs, and people; and major human migrations."

The CSLP list is mostly limited to hazardous or urgent events and hence considers only a small part of the potential applications of SEOS to transient phenomena. It essentially excludes time variant phenomena related to conservation and exploitation of resources.

Only categories 1 and 2 were considered in this study. Although the general outline of the Smithsonian classification is preserved in order to adapt CSLP events to tables such as Table 9, subdisciplinary divisions of these categories are added to permit correlation with the NASA Earth Resources Survey Program discipline objectives. As for the remaining categories, Anthropological Events are of such rarity and potential variety that in all practicality preclude any significant listing of observables, sensor requirements or data requirements at this time.

In February 1973, the World Ecology Report* described CSLP-NASA cooperation in developing the techniques for using ERTS-1 and subsequent satellites for identifying transient phenomena. CSLP will identify such events as are reported by its world-wide scientific reporting network and will inform the NASA-ERTS Operations office with a request for imagery. Analysis of the imagery will establish which types of events are identifiable and in which spectral areas. Once these signatures are established, it is visualized that the future satellite program may be employed to notify the CSLP of the occurrence of pertinent phenomena.

Spatial resolution requirements for observing short lived events from SEOS are estimated to be:

Event	EIFOV**
Volcanic eruption	500 meters
Earthquakes	200 meters
Oil spills	100 - 1500 meters
Animal migration	50 - 500 meters
Water pollution	1500 meters
Air pollution events	500 meters
Landslides	500 meters
Storm surges	500 meters
Vegetation events	50 - 500 meters
Fires	100 - 500 meters
Floods	50 meters
Snowpack changes	50 - 200 meters
Ice break-up	50 meters

*World Ecology Report, Vol. 4, No. 3, Newsletter of International Ecosystem and Environmental Management, Washington, D. C., February 5, 1973.

**These resolutions are the Effective Instantaneous Field of View (EIFOV) required to assess radiation characteristics on the spatial level (as defined by AISWG, Dec. 1972). To assess shape related characteristics, one may require 5 or more EIFOVs within the confines of a target area. Some EIFOVs may need to be multiplied by a factor of 3 to obtain equivalent photographic resolution.

Over the past five years, the total number of short lived events reported by the Smithsonian has averaged over 100 per year. The CSLP estimates an average of 35 satellite - detectable events per year based on current technology. The following is the CSLP event participation since the program started in 1968.

EVENTS	1968	1969	1970	1971	1972	Total
Geophysical Events						
Volcanic Erupsions	12	18	22	19	16	87
Earthquakes	18	29	19	20	16	102
Landslides, Landslips, and Avalanches	1	7	2	2	4	16
Storm surges, Tidal Waves, and Floods	1	4	4	2	6	17
Unusual geological events	3	5	5	2	0	15
Astronomical Events						
Major Fireballs	12	14	8	6	6	46
Meteorite falls	1	5	5	4	0	15
Biological Events						
Fauna mortalities, migrations, population fluctuations, infestations, colonizations, outbreaks, invasions, and plagues.	8	29	20	17	17	91
Oil and Water pollution	9	20	22	20	25	96
Flora mortalities, algal blooms, diseases, etc.	2	4	3	2	3	14
Urgent Anthropological Events	0	2	1	1	0	4
Urgent Archaeological Events	1	3	0	0	0	4
Others	2	5	2	4	6	19
TOTAL EVENTS	70	145	113	99	99	526

Applications discussed in detail in Appendices A through F have considered Short Lived Phenomena included in those earth science and biological events categorized by the CSLP which are also potential applications for SEOS. However, subdisciplinary classifications are not those of CSLP but are restricted to satellite-detectable events in the main correlative with NASA concepts of objectives. The broad classifications of Earth Science or Biological events is conceptually pertinent to the Smithsonian natural history approach to the various phenomena. For example, oil slicks and SO_2 emission are related by CSLP to environment and ecology and hence are biological.

The specific applications listed are defined as the ultimate goal for which SEOS data can be used. Entries in the tables and appendices include identification of the user, a description of observable and associated phenomena , a time line for the event (where applicable), satellite, sensor and data requirements (where possible), and assessment of the goals and uniqueness of the SEOS system. Because of the nature of short lived phenomena the entries related to observation requirement, (number of targets, etc.), data requirements and interim activities are included only for example. The actual scope, intensity and unique character of any short lived event will dictate the actual observation requirements and data needs.

Events classified by CSLP and used in developing various applications on mission objectives include:

<u>Earth Science Events</u>

- Geology
  - Volcanism
  - Seismic
  - Earth movement
- Hydrological
  - Floods
  - Snowpack
- Geographical
  - Polar, Sub-polar
- Meteorological
  - Severe storms

Biological Science Events

- Environment
  - Water Pollution
  - Air Pollution
- Ecological
  - Fauna
  - Flora
- Forest and Range
  - Fires

Future studies should attempt to enlarge the list to include such oceanographic phenomena as upwellings and fish migration, such agricultural events stress and harvest times, and such geographical items as sandstorms and delta changes.

APPENDIX H
Reviewers

APPENDIX H

REVIEWERS

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D. Holmes - EPA
J. Jarmin - U.S. Army Corps of Engr.
W. E. Kibler - USDA
A. Park - Earth Sat.
E. Pastula - NOAA
C. J. Robinove - USGS
J. Sherman - NOAA
D. Simonett - Earth Sat.
W. H. Stevenson - NOAA
E. L. Tilton - NASA/ERL
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